US010533780B2

(12) United States Patent
Yi et al.

(10) Patent No.: US 10,533,780 B2
(45) Date of Patent: Jan. 14, 2020

(54) **FEEDBACK DEVICE AND METHOD OF PROVIDING THERMAL FEEDBACK USING THE SAME**

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(72) Inventors: **Kyoung Soo Yi**, Daejeon (KR); **Ock Kyun Oh**, Daejeon (KR); **Se Hwan Lim**, Daejeon (KR)

(73) Assignee: **TEGWAY CO., LTD.**, Daejeon (KR)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 26 days.

(21) Appl. No.: **15/858,351**

(22) Filed: **Dec. 29, 2017**

(65) **Prior Publication Data**

US 2019/0063797 A1 Feb. 28, 2019

(30) **Foreign Application Priority Data**

Aug. 31, 2017 (KR) 10-2017-0111462
Aug. 31, 2017 (KR) 10-2017-0111463
(Continued)

(51) **Int. Cl.**
F25B 21/04 (2006.01)
A41D 1/00 (2018.01)

(52) **U.S. Cl.**
CPC ***F25B 21/04*** (2013.01); *A41D 1/002* (2013.01); *F25B 2321/0212* (2013.01); *F25B 2321/0252* (2013.01)

(58) **Field of Classification Search**
CPC F25B 21/04; F25B 2321/0212; F25B 2321/0252; A41D 1/002; A41D 13/005;
(Continued)

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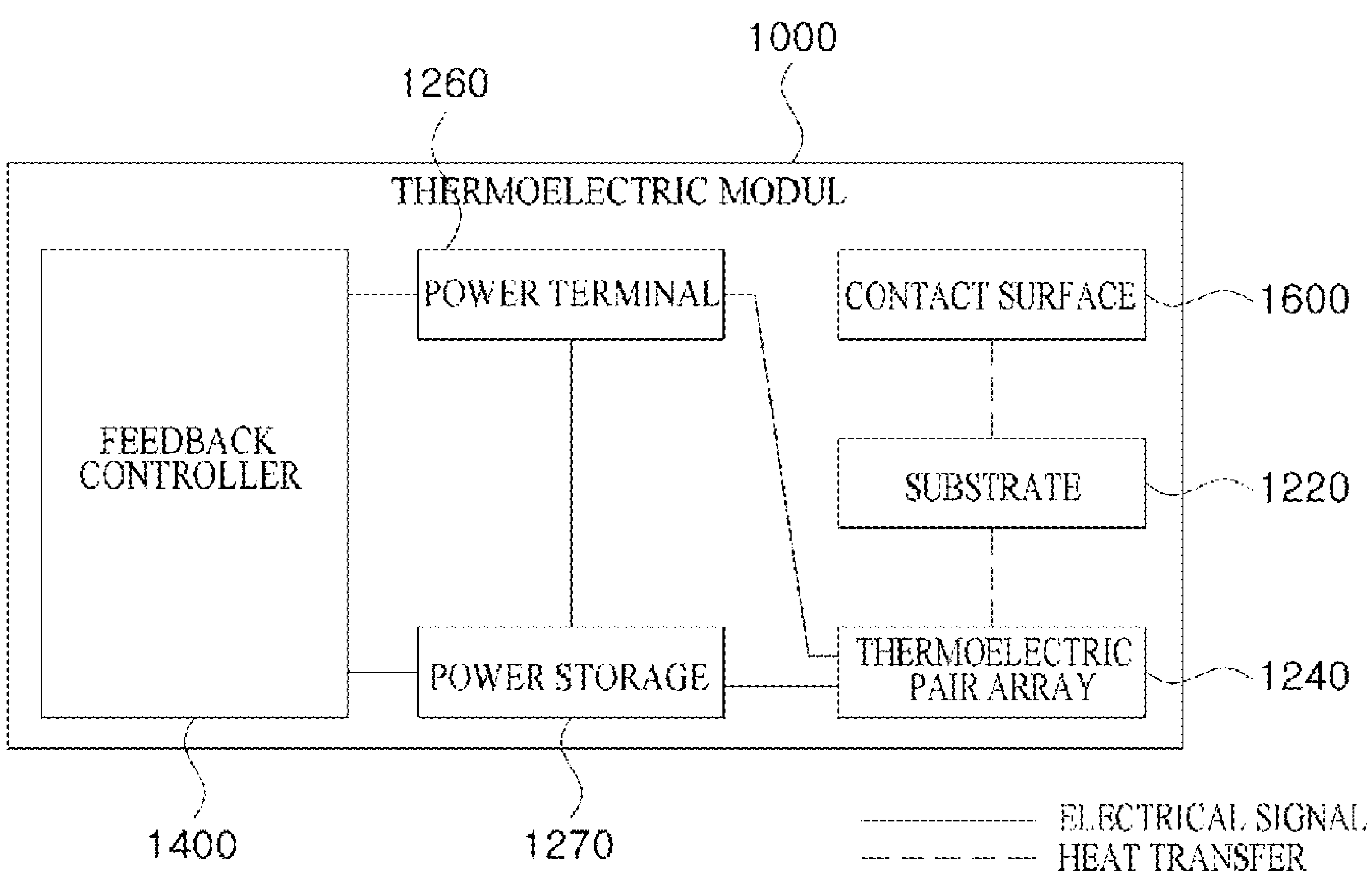
Primary Examiner — Ryan W Sherwin
(74) *Attorney, Agent, or Firm* — Maschoff Brennan

(57) **ABSTRACT**

Disclosed herein are a feedback device and a method of providing thermal feedback using the same. The feedback device according to an embodiment of the present disclosure includes a thermoelectric module including a substrate having flexibility, a thermoelement disposed on the substrate and configured to perform a thermoelectric operation for thermal feedback, and a contact surface disposed on the substrate, and configured to transfer heat generated through the thermoelectric operation to a user through the substrate and the contact surface to output the thermal feedback; and a feedback controller configured to control the thermoelectric module, and wherein the feedback controller controls the thermoelectric module so that, after a temperature of the contact surface reaches a maximum temperature, the temperature of the contact surface is maintained within a predetermined temperature range during an entire thermoelectric operation time interval.

19 Claims, 65 Drawing Sheets



(30) **Foreign Application Priority Data**

Aug. 31, 2017	(KR)	10-2017-0111464
Aug. 31, 2017	(KR)	10-2017-0111465
Aug. 31, 2017	(KR)	10-2017-0111466
Aug. 31, 2017	(KR)	10-2017-0111467

(58) **Field of Classification Search**

CPC A41D 13/0051; A41D 13/0053; G06F 3/016; G08B 6/00; A47C 7/74; A47C 7/742; A47C 7/748; A47C 7/72; A61F 7/00; B60N 2/56; B60N 2/5678

See application file for complete search history.

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KR	20170089441	A	8/2017

* cited by examiner

FIG. 1

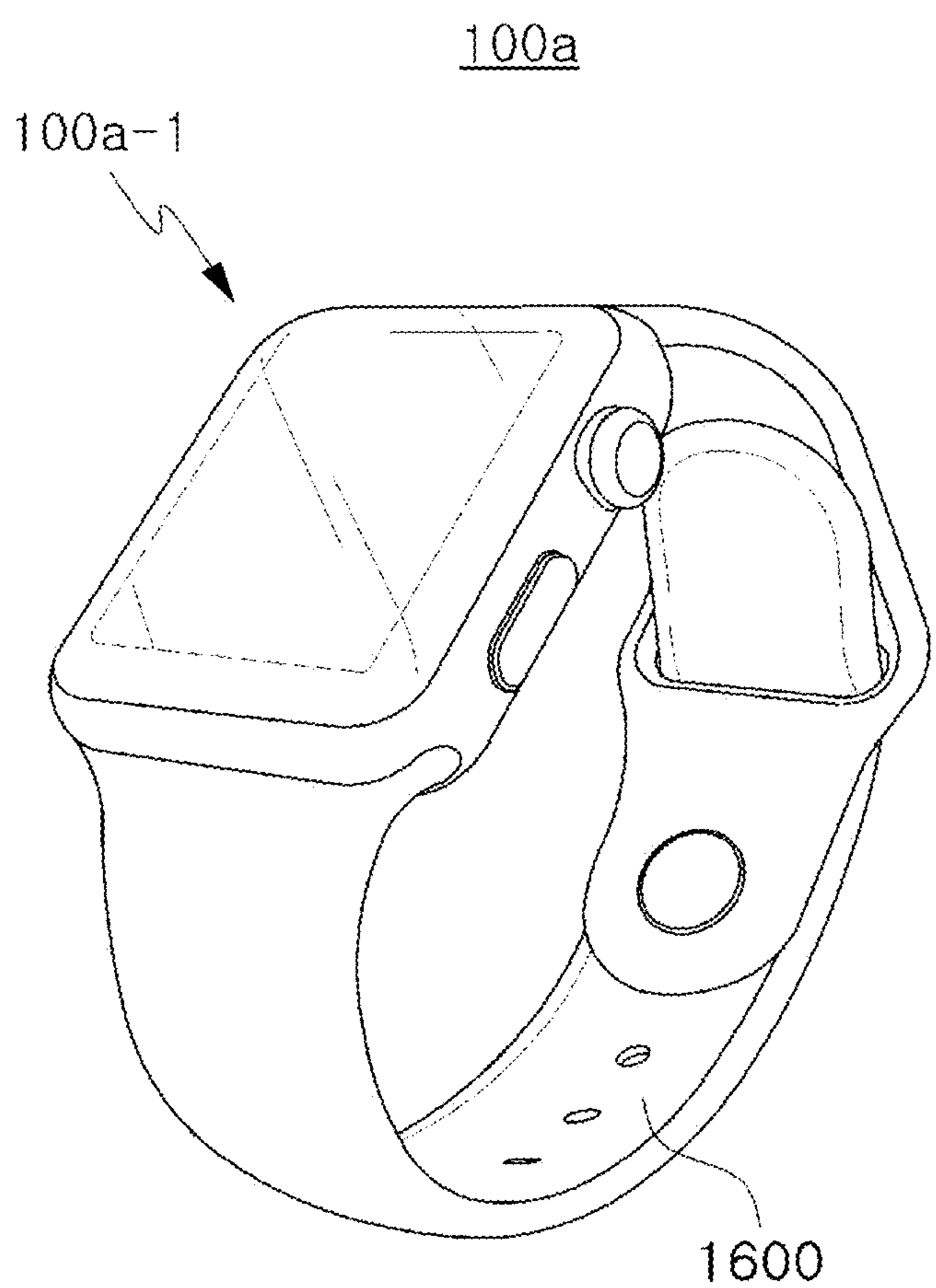


FIG. 2

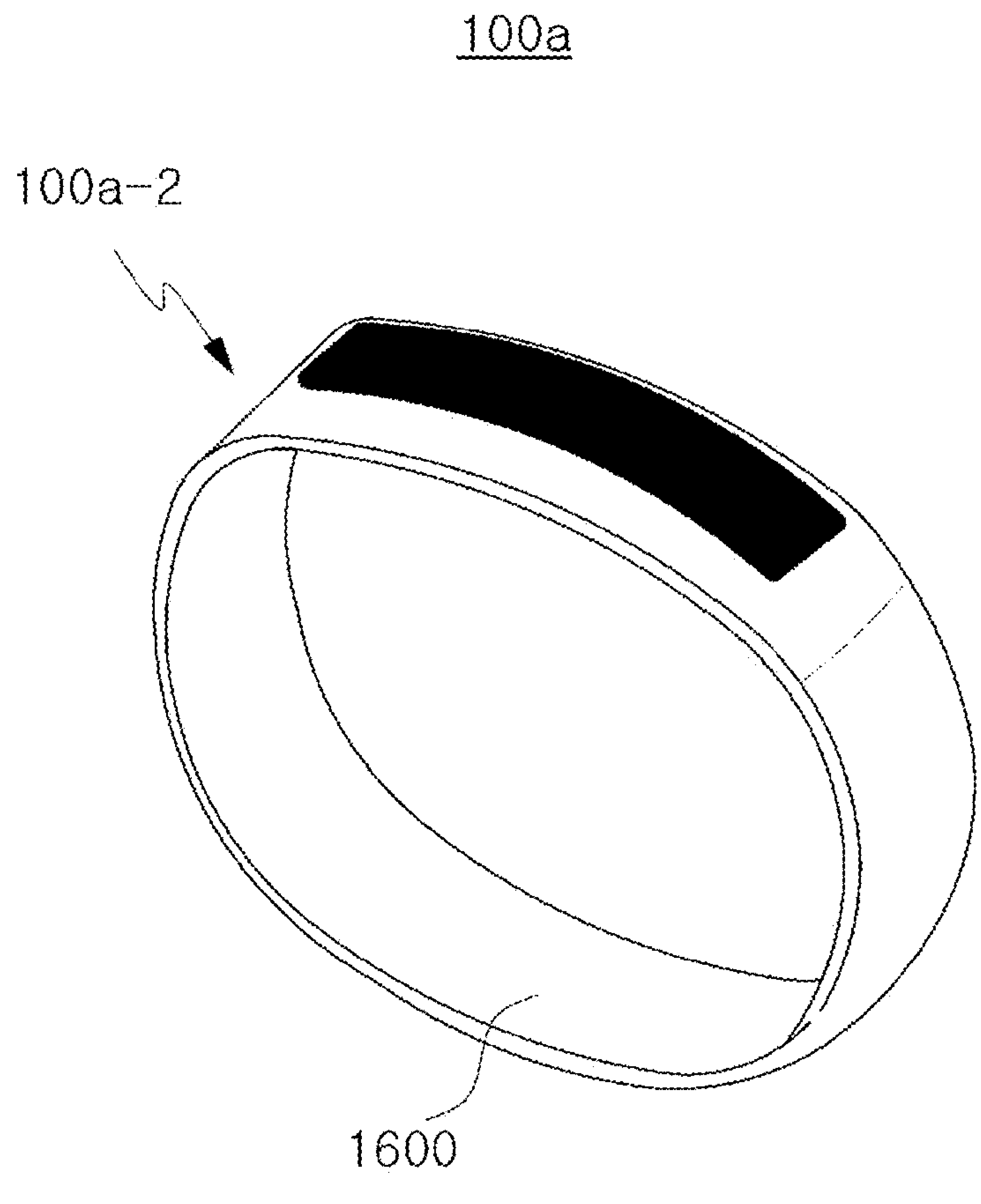


FIG. 3

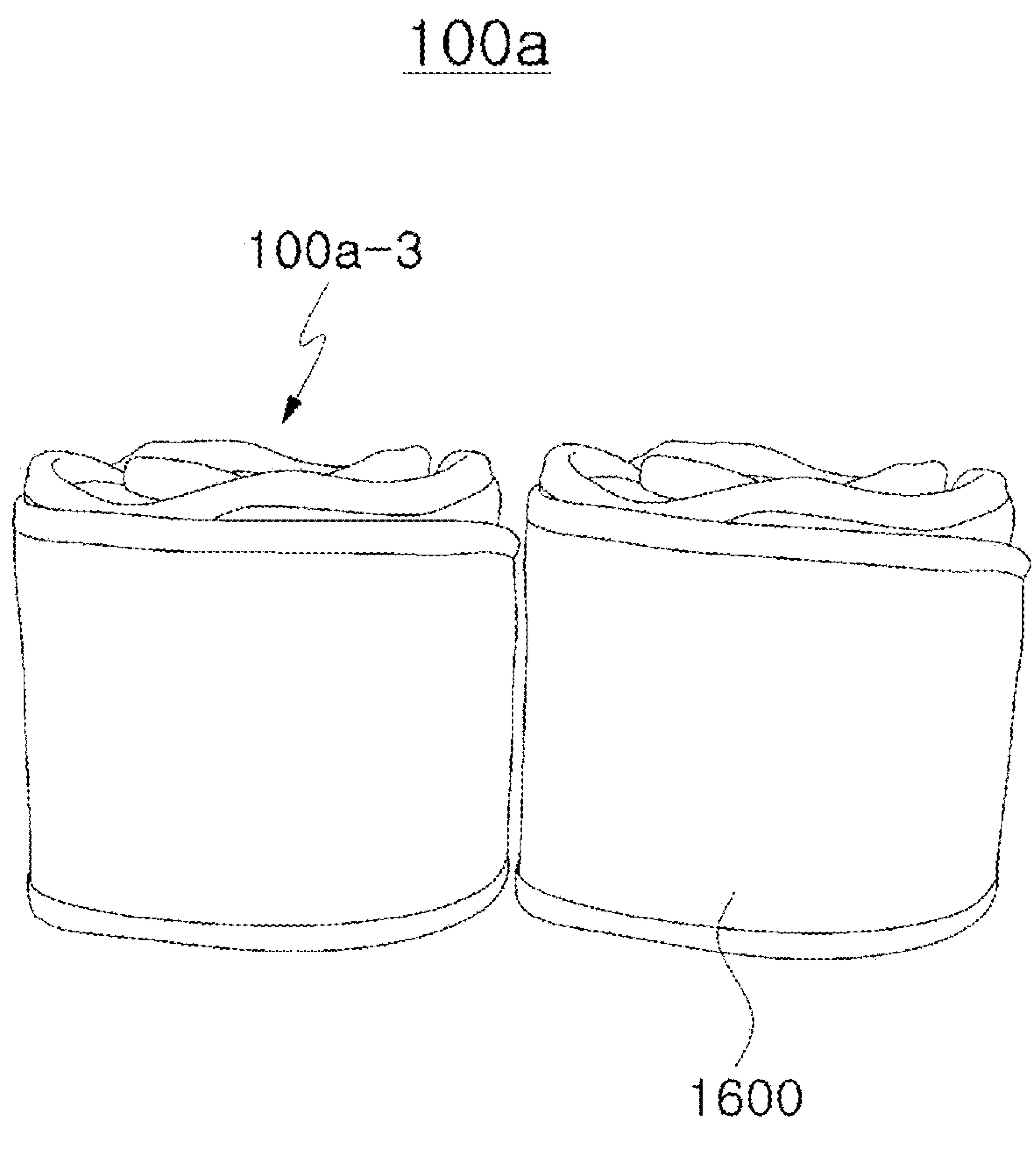


FIG. 4

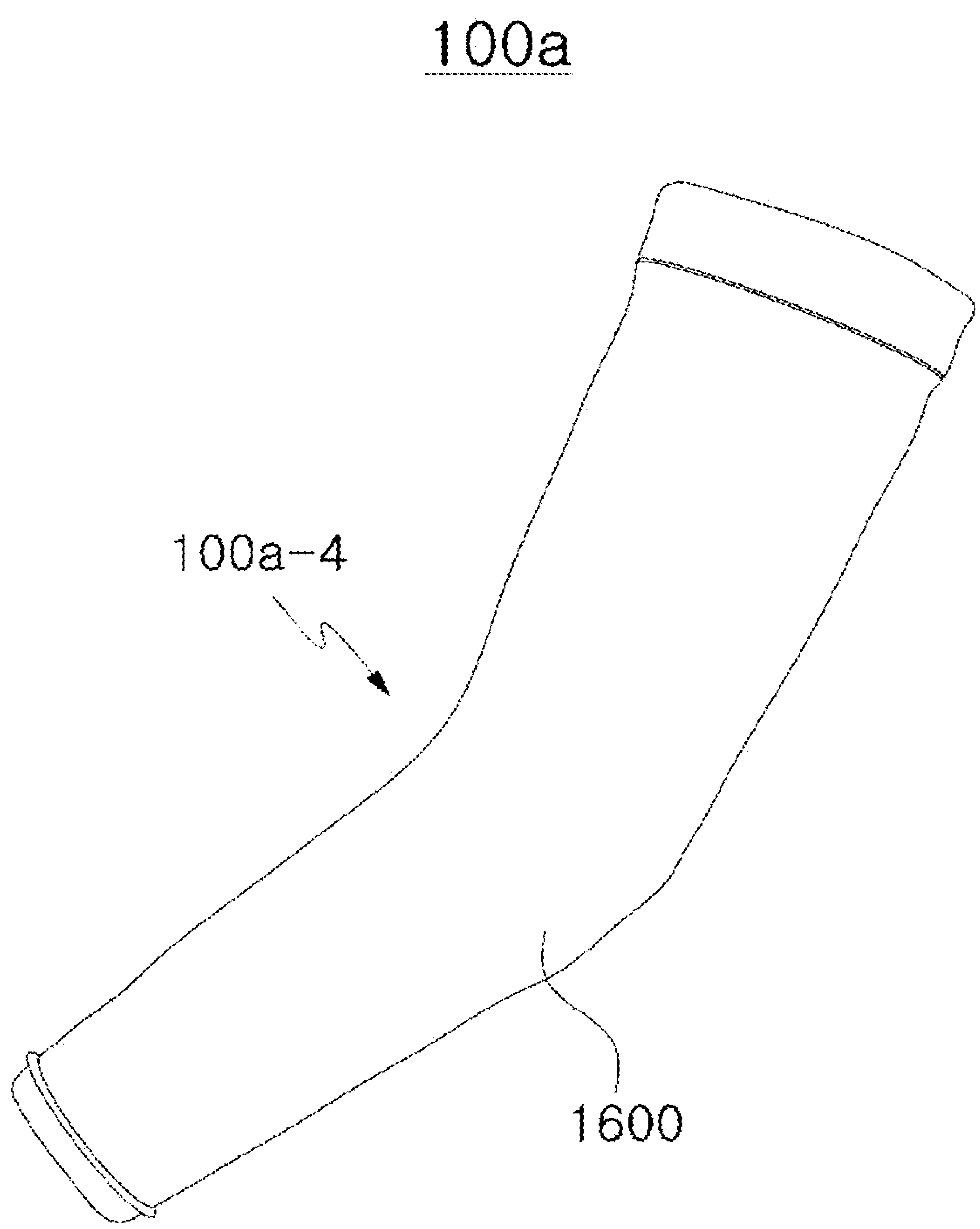


FIG. 5

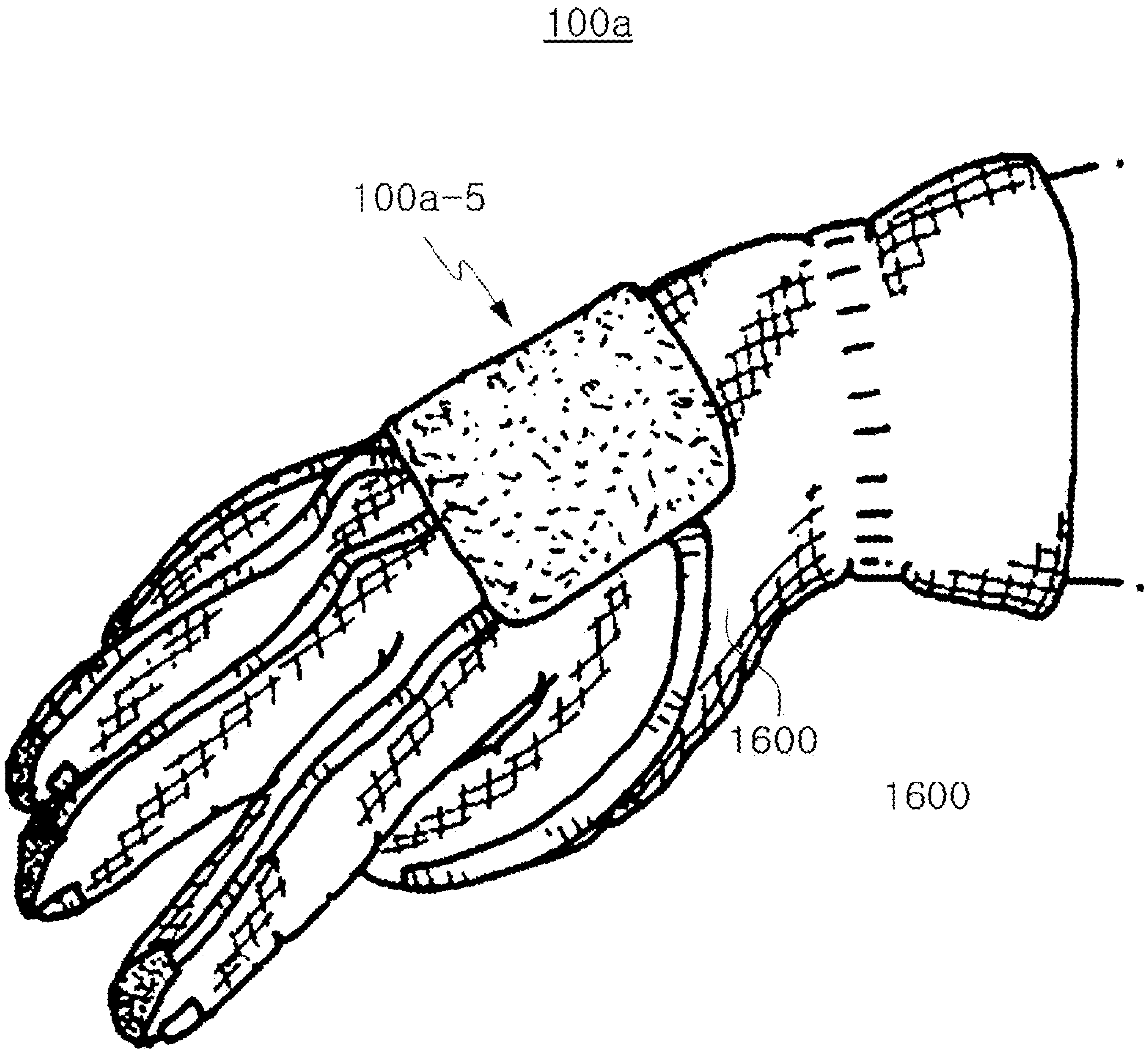


FIG. 6

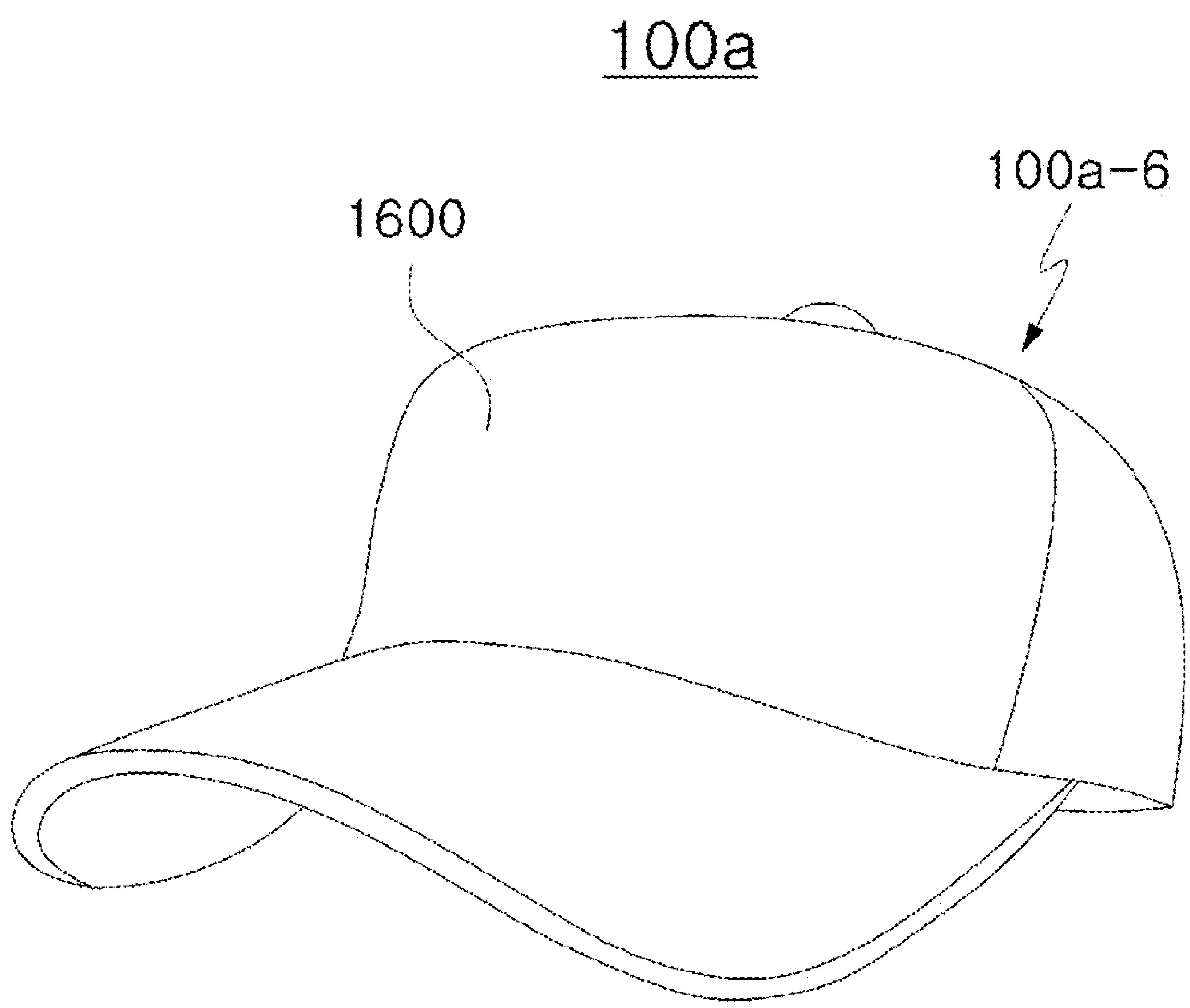


FIG. 7

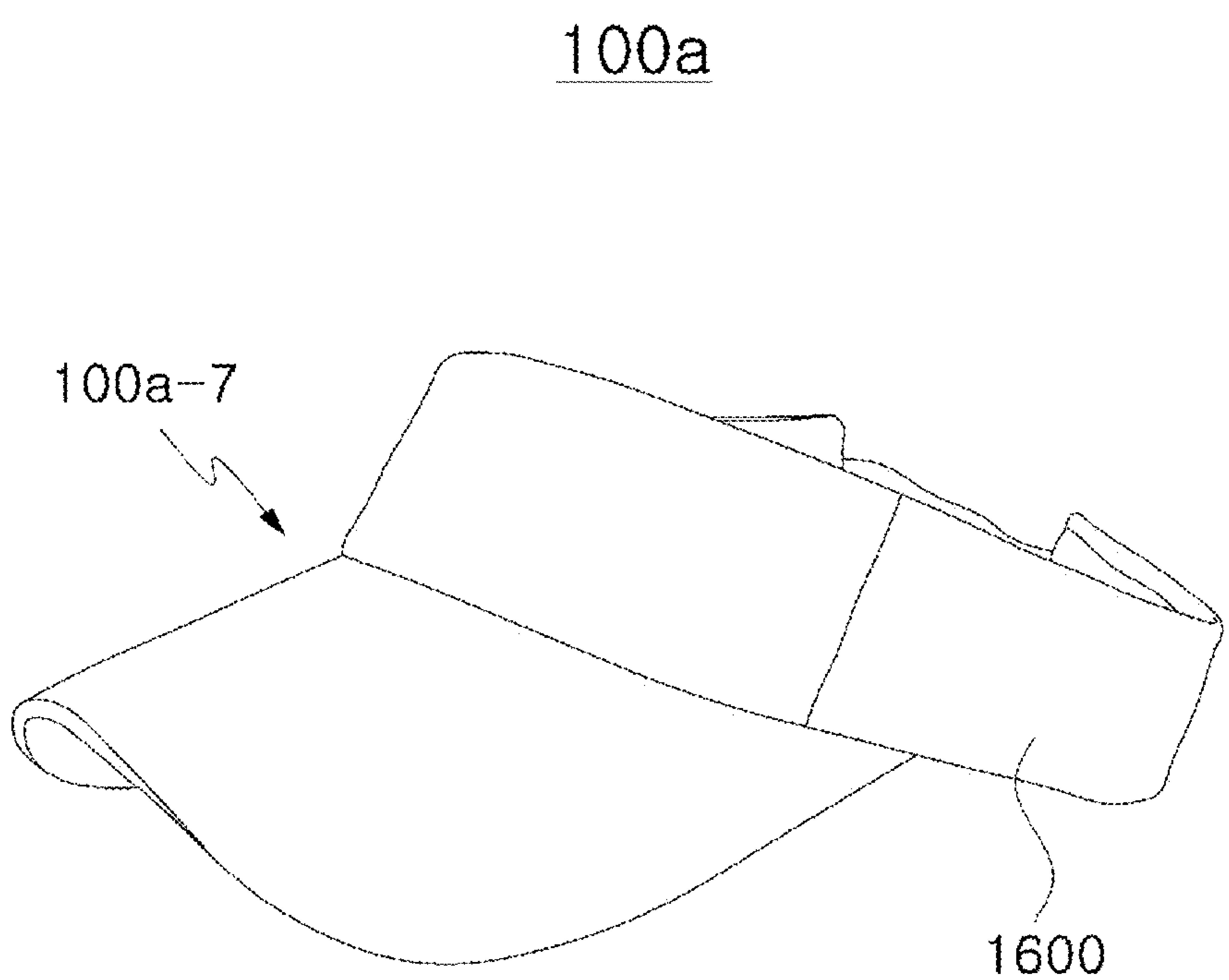


FIG. 8

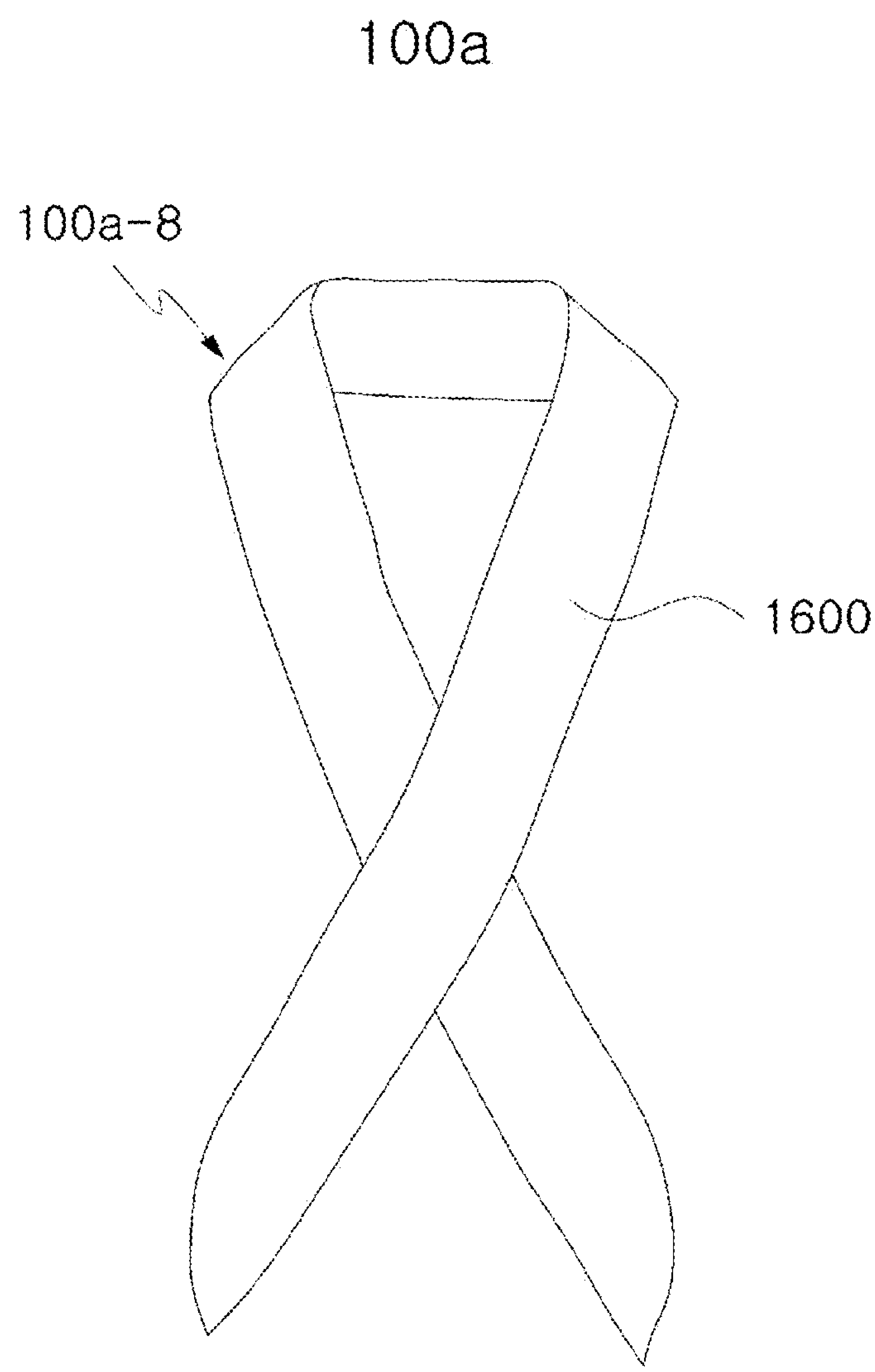


FIG. 9

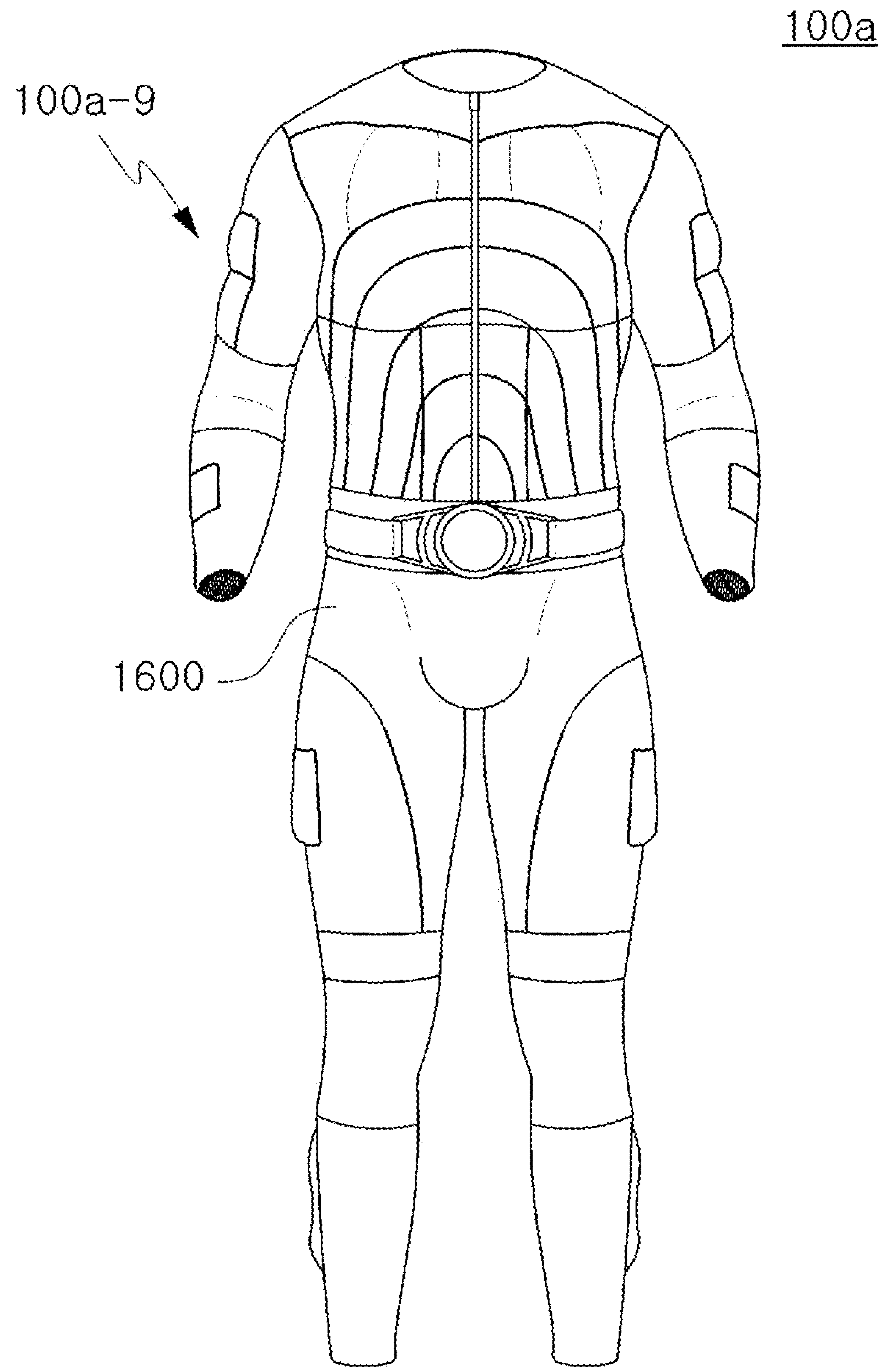


FIG. 10

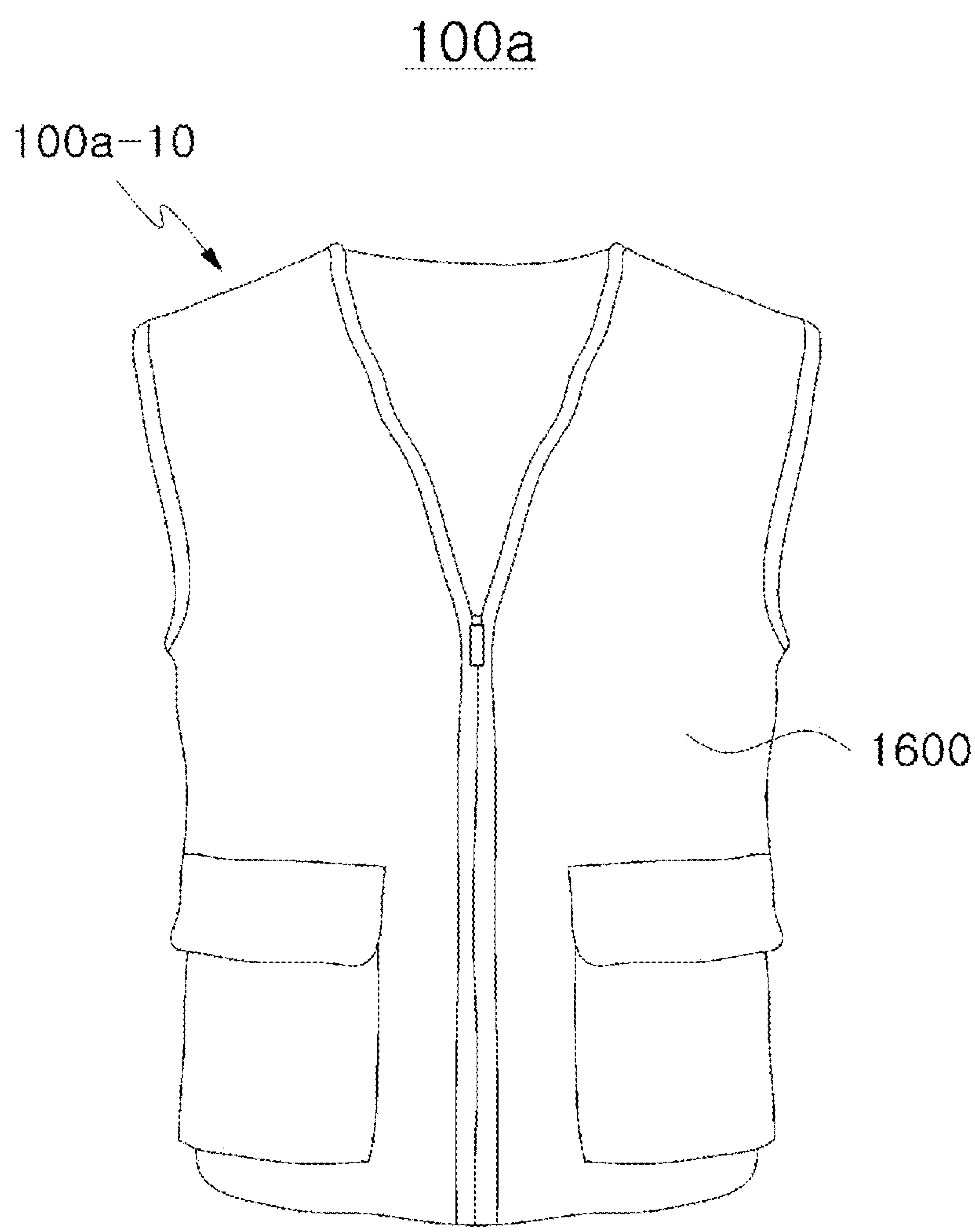


FIG. 11

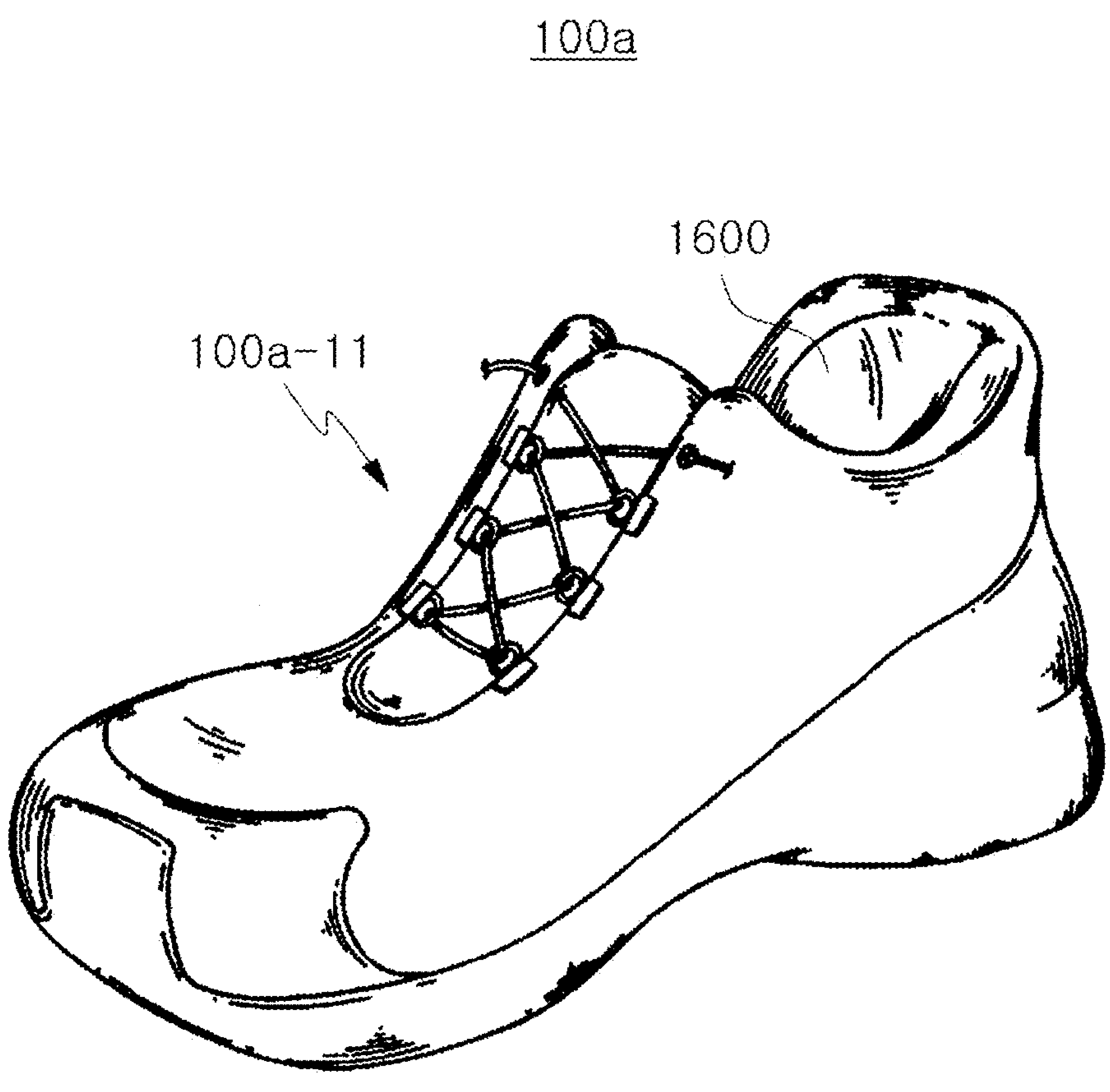


FIG. 12

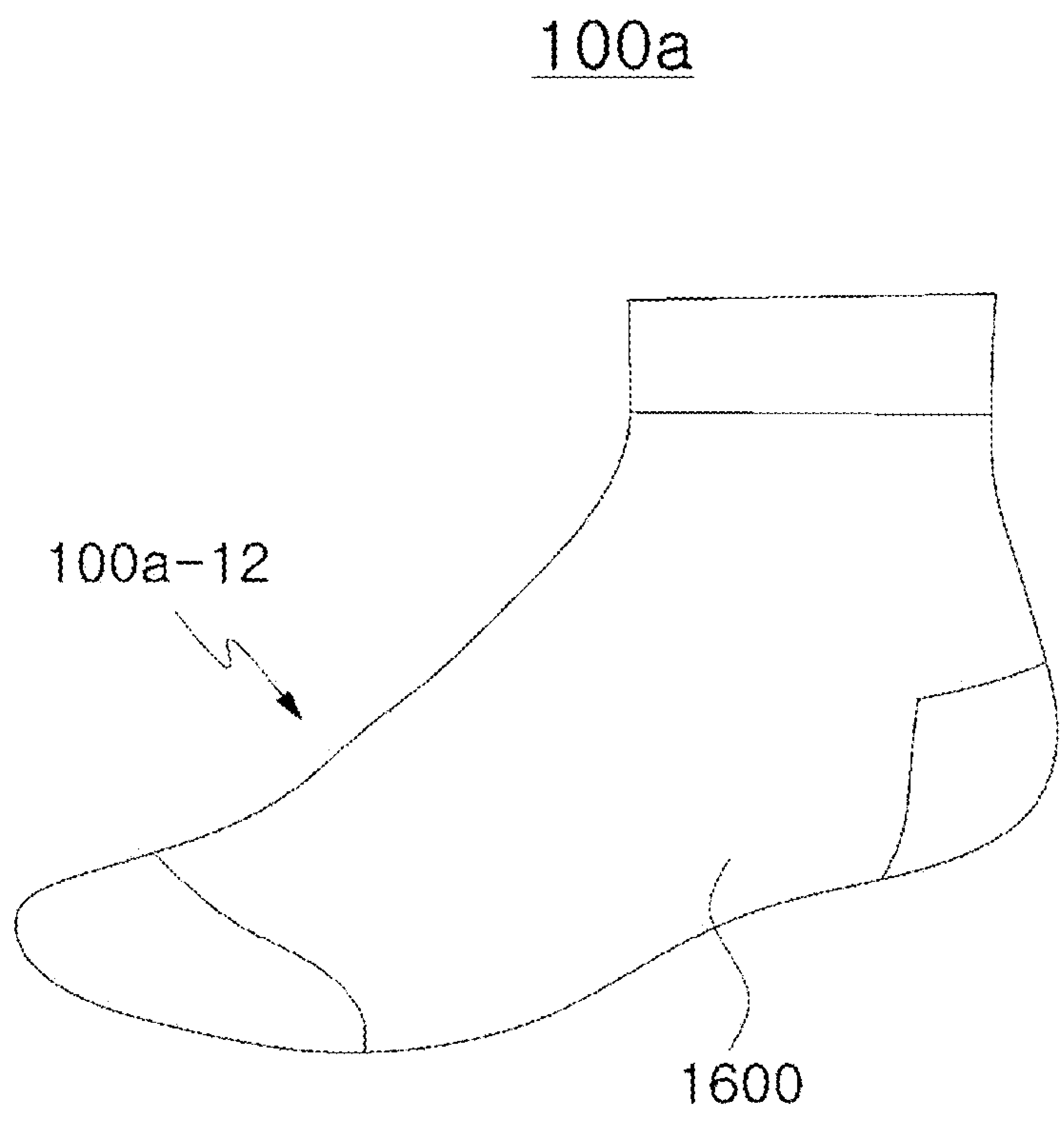


FIG. 13

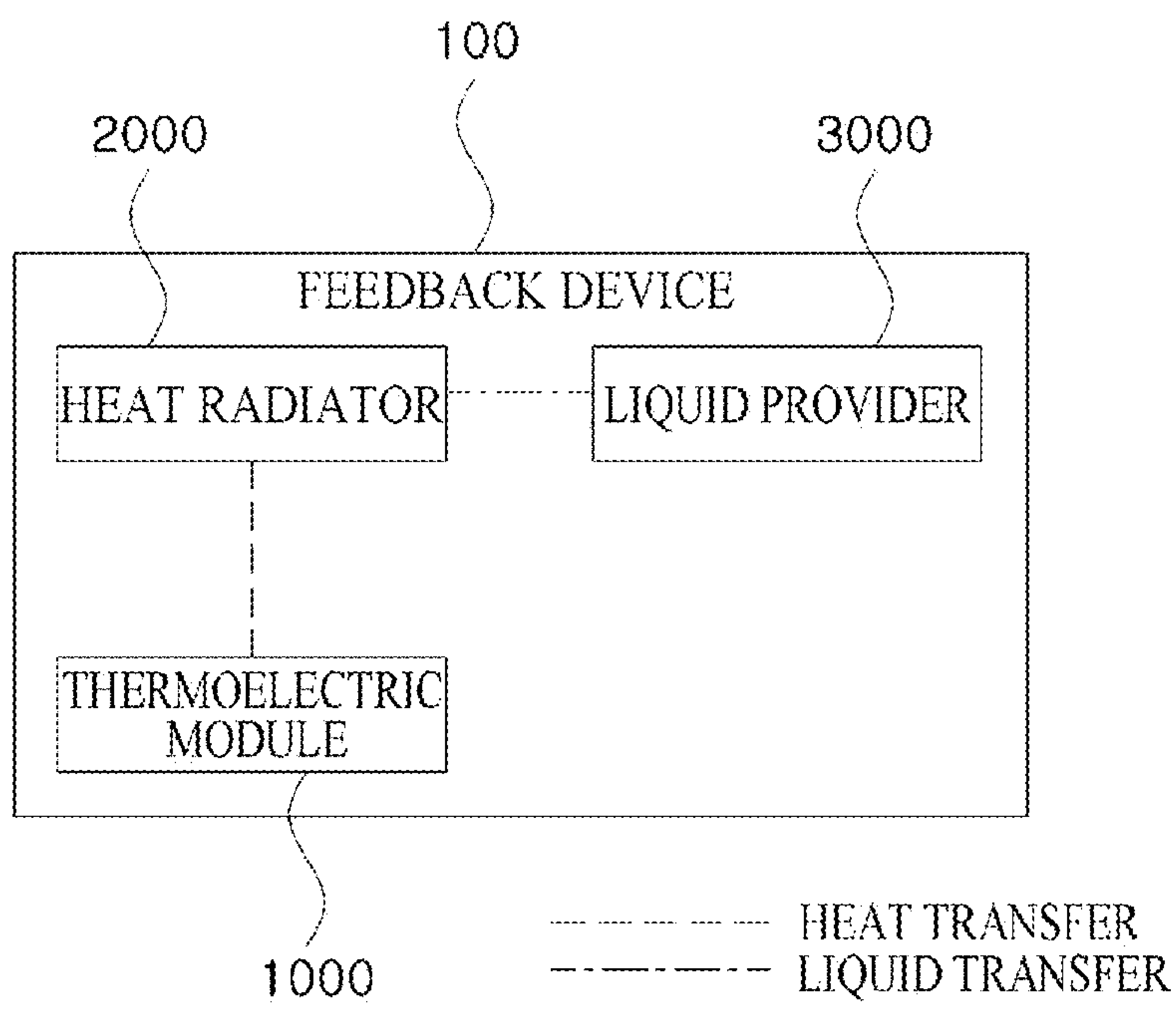

100
2000
3000
FEEDBACK DEVICE
HEAT RADIATOR
LIQUID PROVIDER
THERMOELECTRIC MODULE
1000
HEAT TRANSFER
LIQUID TRANSFER

FIG. 14

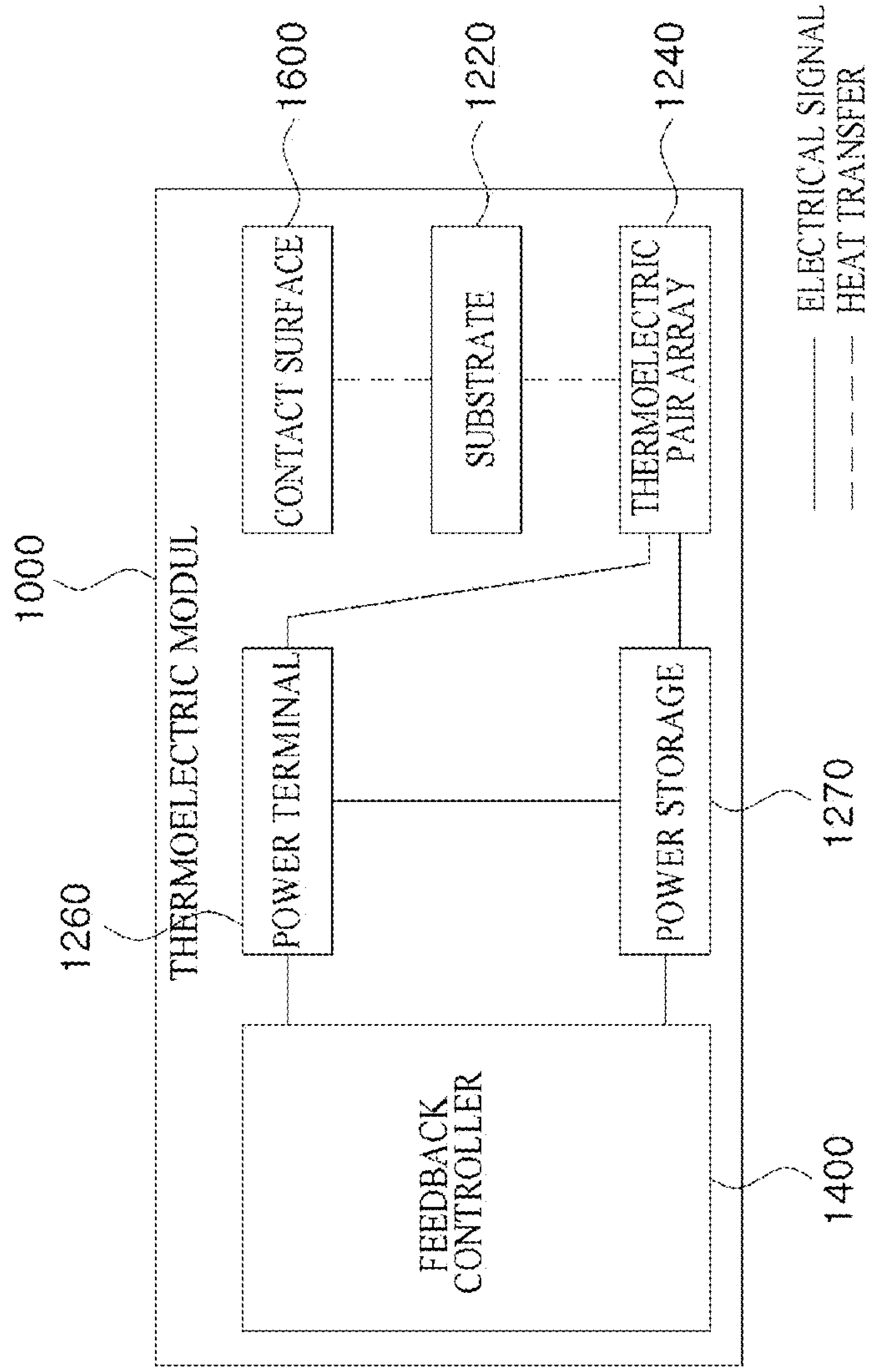

1000
THERMOELECTRIC MODUL
1600
CONTACT SURFACE
1220
SUBSTRATE
1240
THERMOELECTRIC PAIR ARRAY
1260
POWER TERMINAL
1270
POWER STORAGE
FEEDBACK CONTROLLER
1400
ELECTRICAL SIGNAL
HEAT TRANSFER

FIG. 15

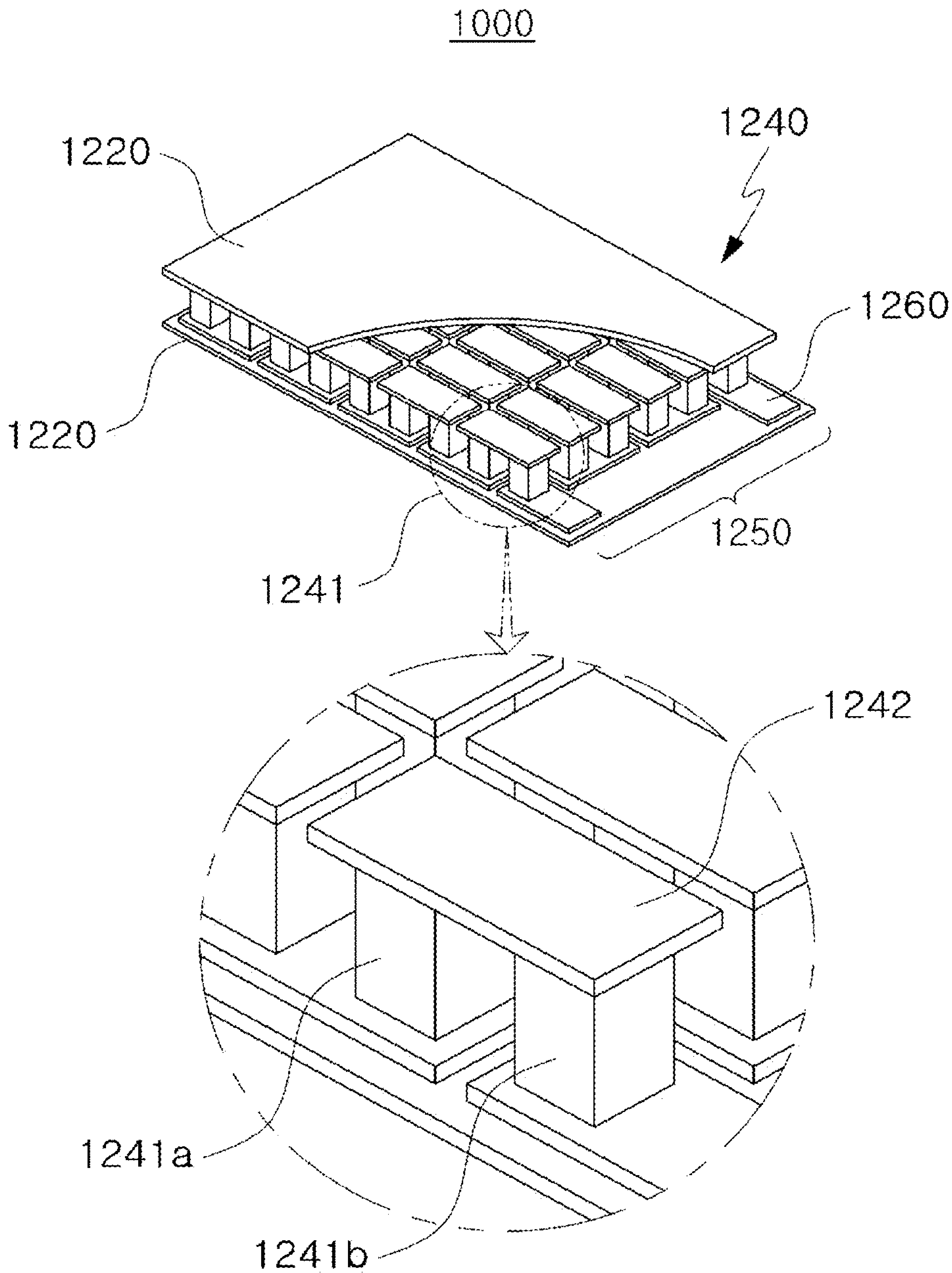


FIG. 16

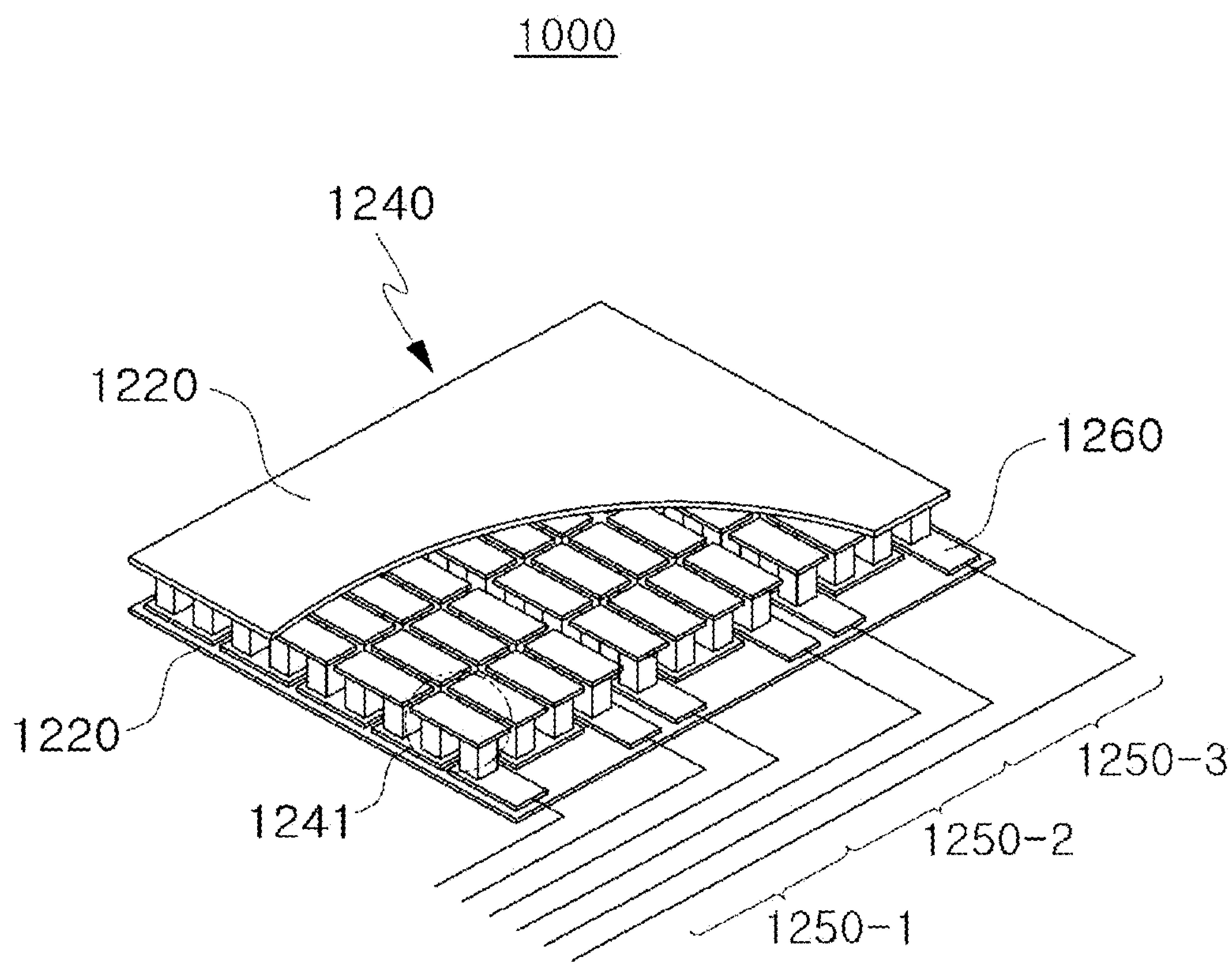


FIG. 17

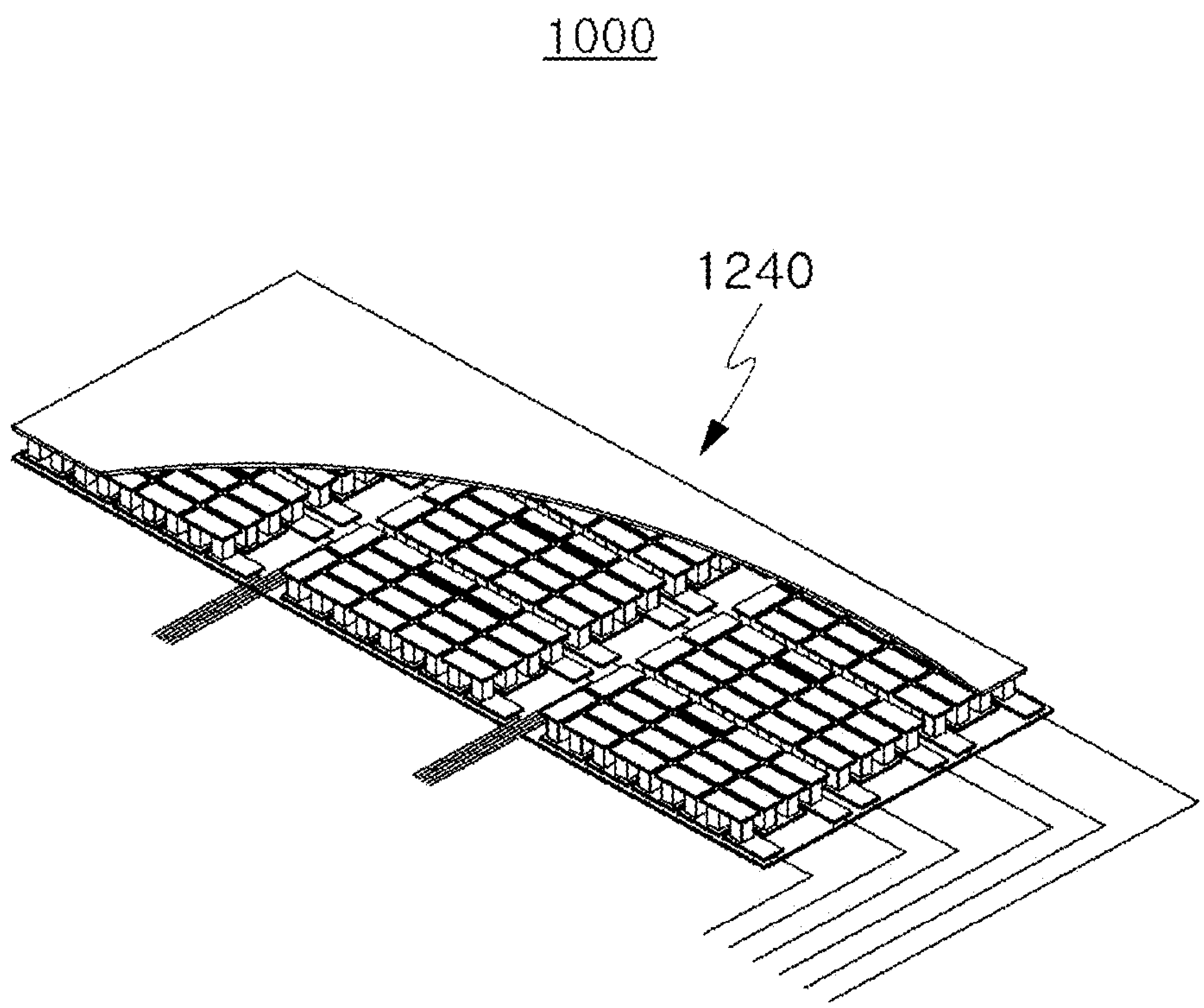


FIG. 18

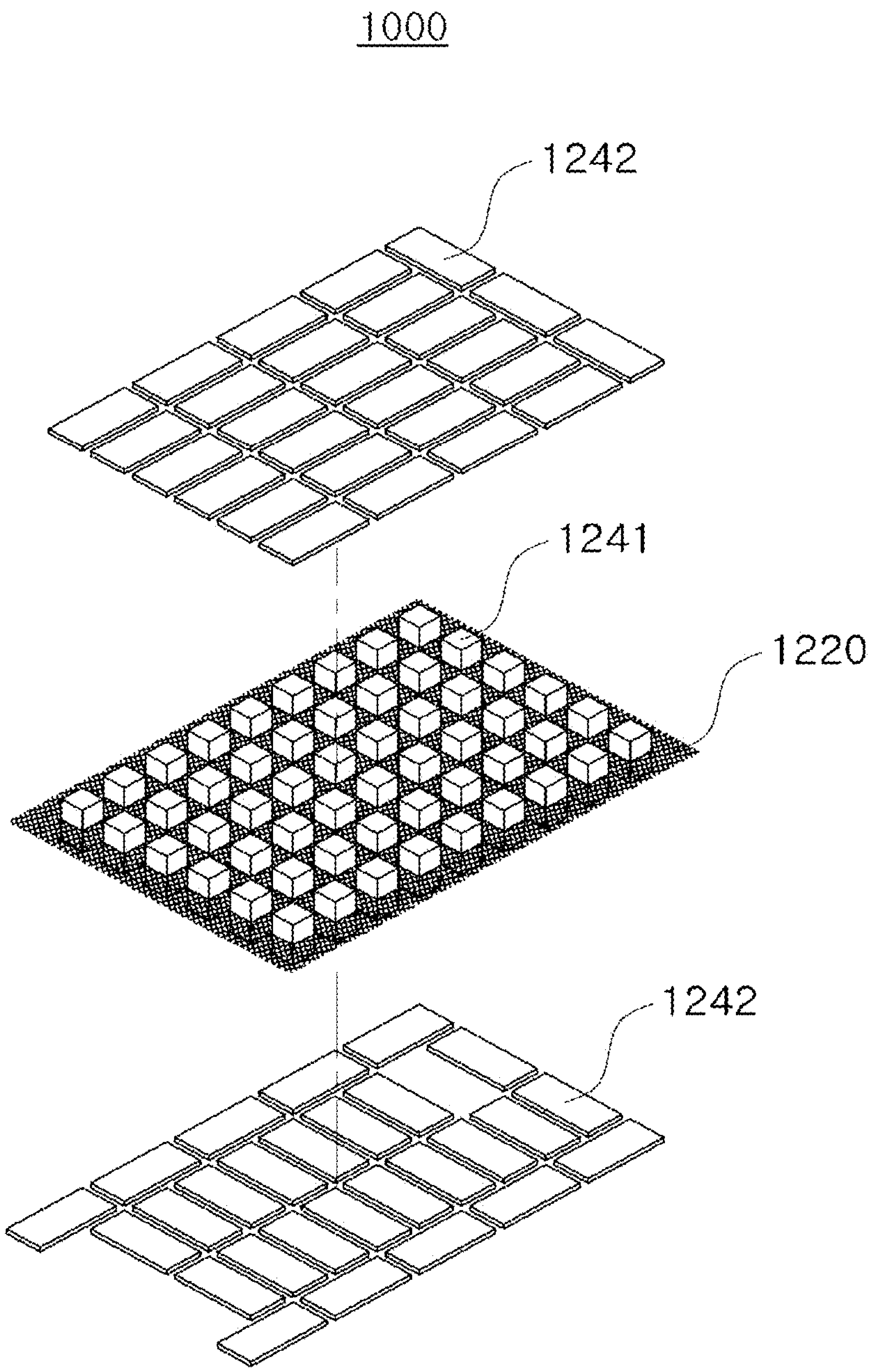


FIG. 19

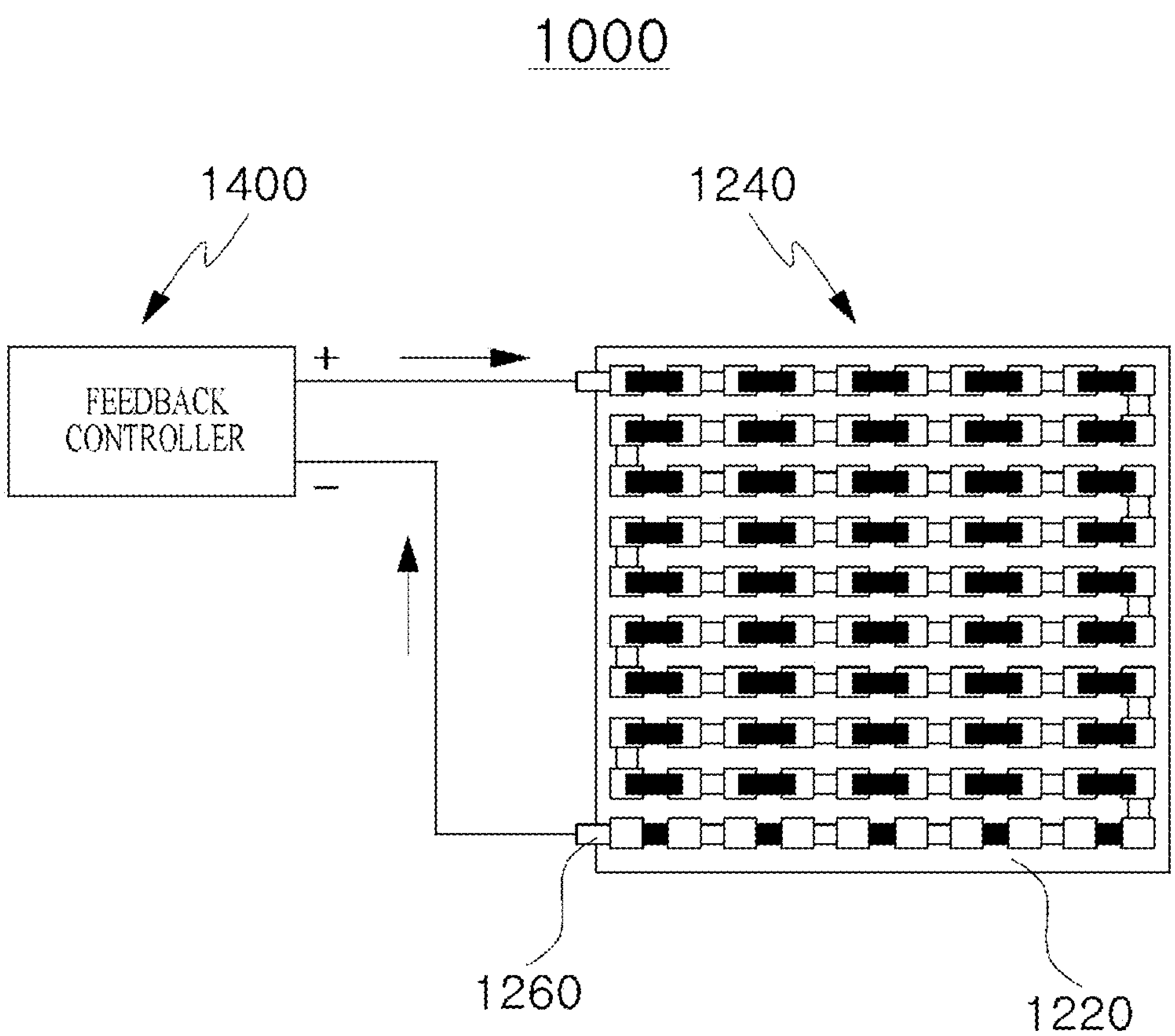


FIG. 20

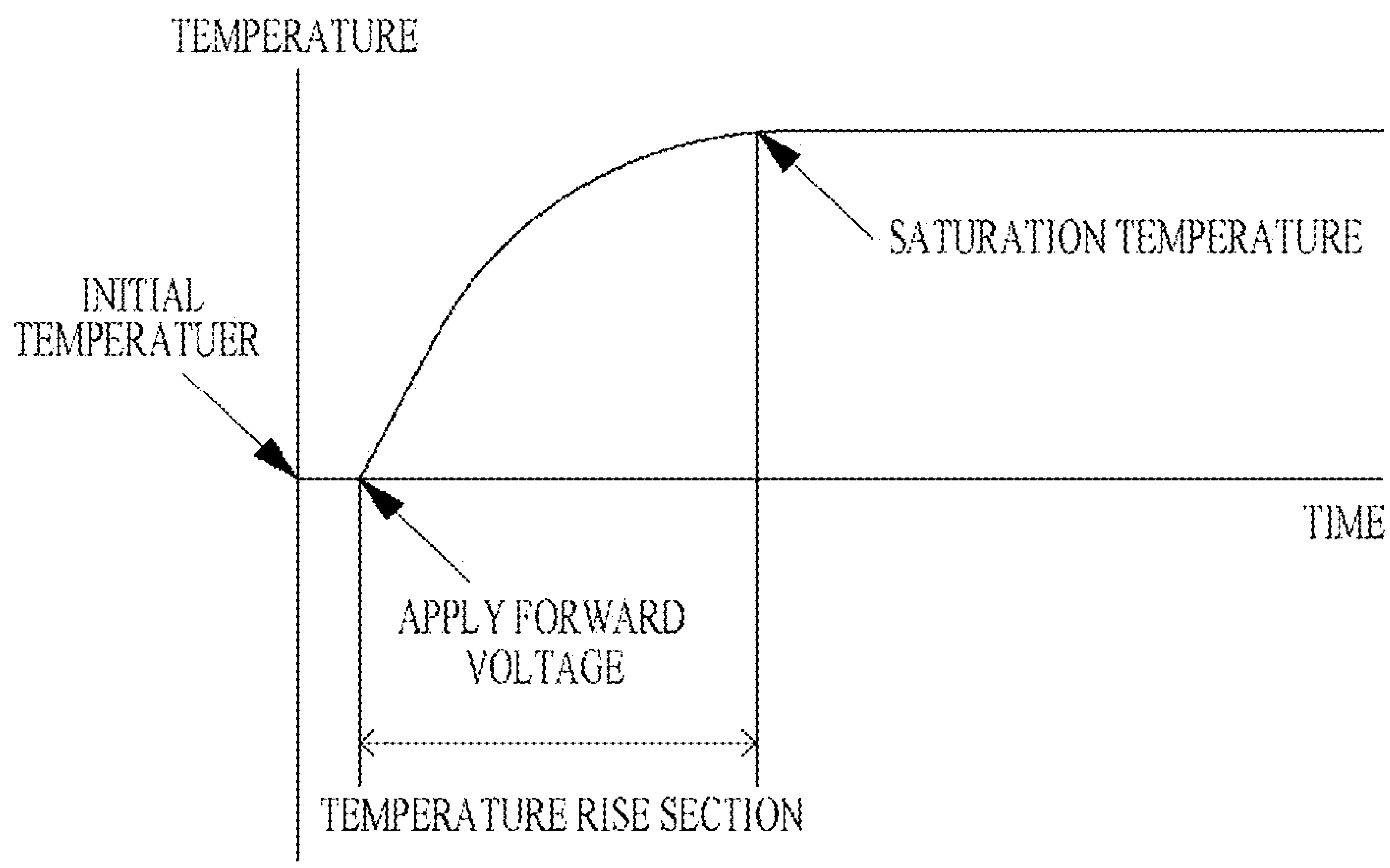

TEMPERATURE
SATURATION TEMPERATURE
INITIAL
TEMPERATUER
TIME
APPLY FORWARD
VOLTAGE
TEMPERATURE RISE SECTION

FIG. 21

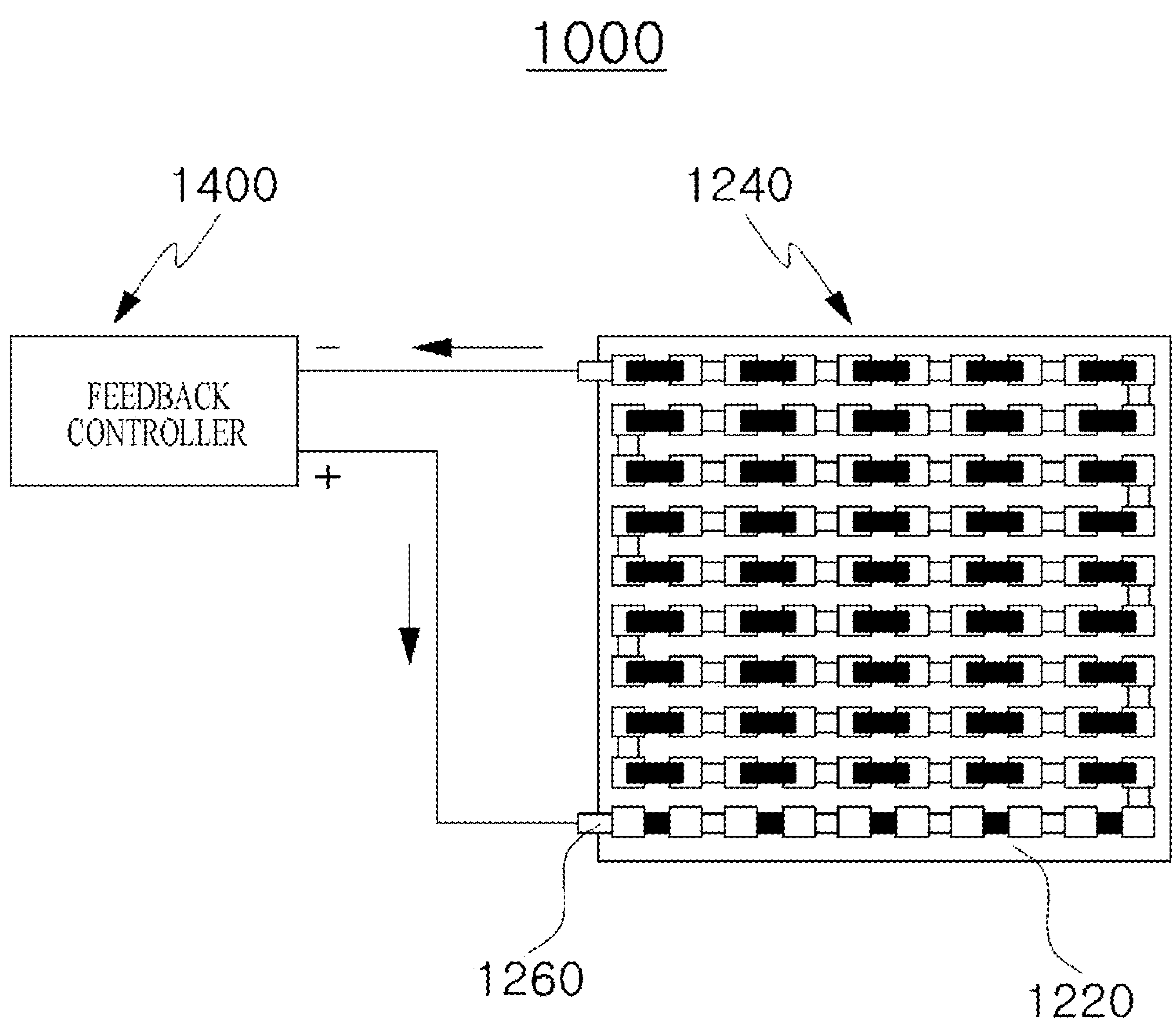
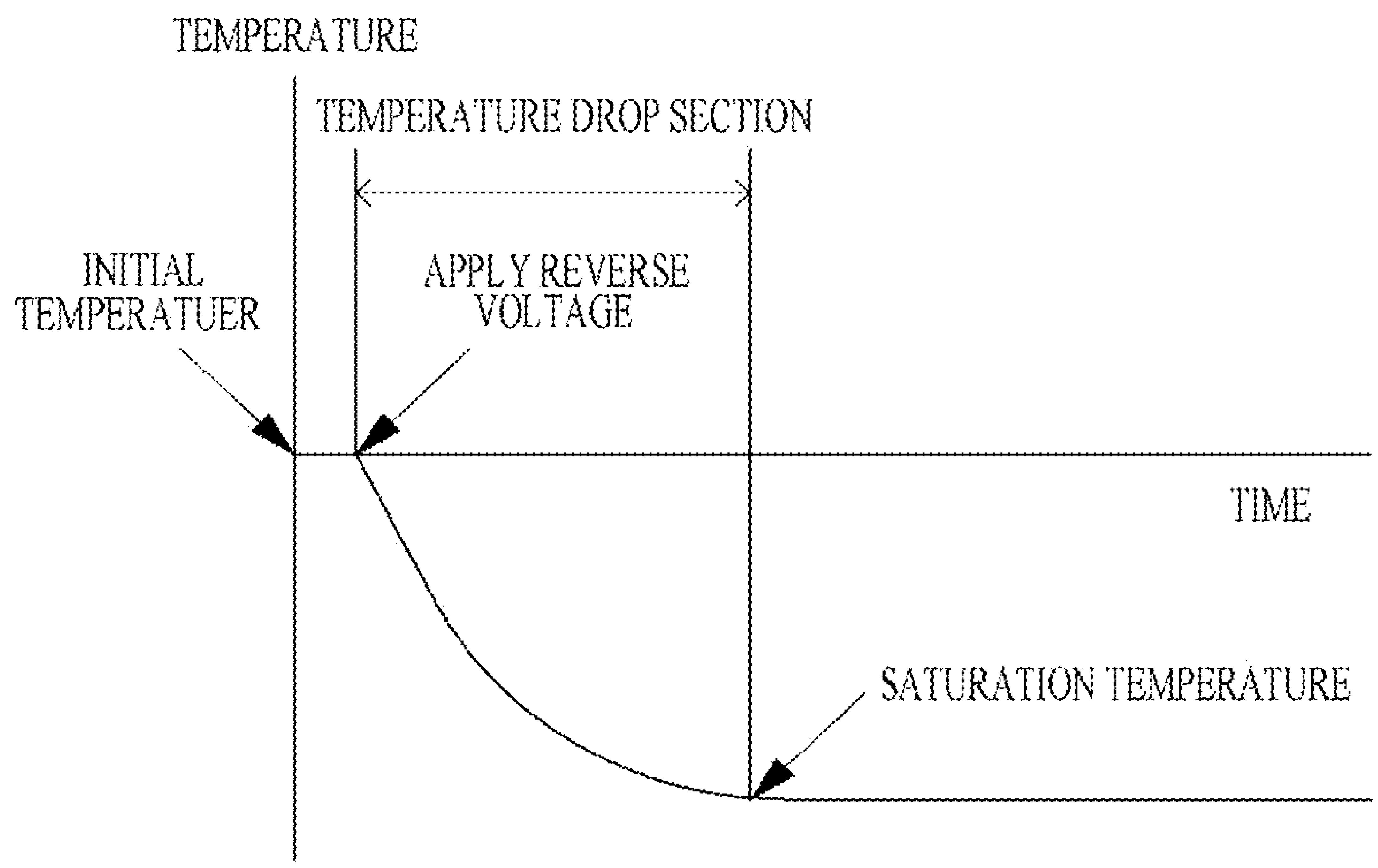
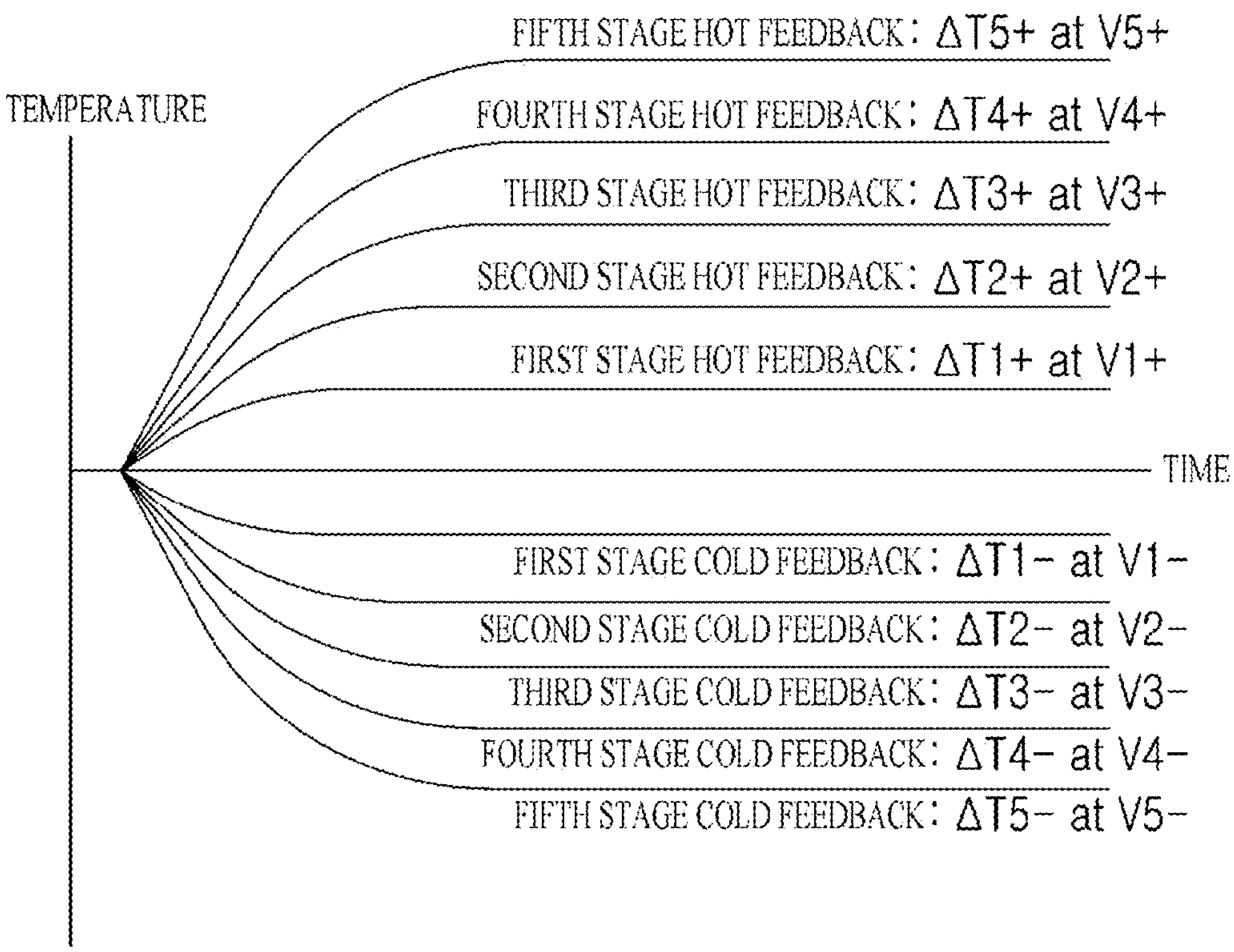


FIG. 22



TEMPERATURE
TEMPERATURE DROP SECTION
INITIAL TEMPERATUER
APPLY REVERSE VOLTAGE
TIME
SATURATION TEMPERATURE

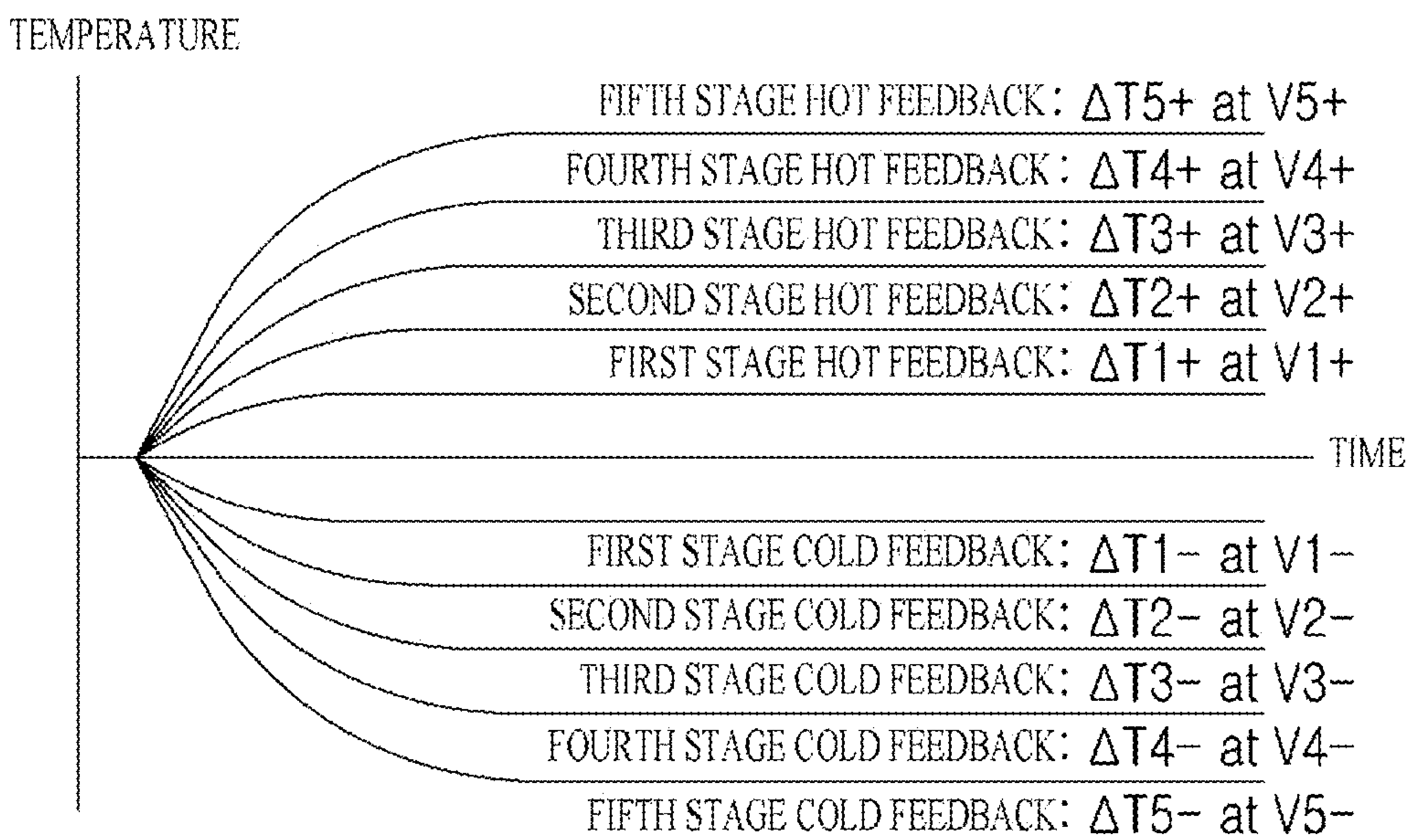
FIG. 23



$V1+/V1-=V2+/V2-=V3+/V3-=V4+/V4-=V5+/V5-=-1$

$|\Delta T1+|>|\Delta T1-|,\ |\Delta T2+|>|\Delta T2-|,\ |\Delta T3+|>|\Delta T3-|,\ |\Delta T4+|>|\Delta T4-|,\ |\Delta T5+|>|\Delta T5-|$

FIG. 24



$\Delta T1+/\Delta T1- = \Delta T2+/\Delta T2- = \Delta T3+/\Delta T3- = \Delta T4+/\Delta T4- = \Delta T5+/\Delta T5- = -1$

$|V1+|<|V1-|$, $|V2+|<|V2-|$, $|V3+|<|\Delta T3-|$, $|V4+|<|V4-|$, $|V5+|<|V5-|$

FIG. 25

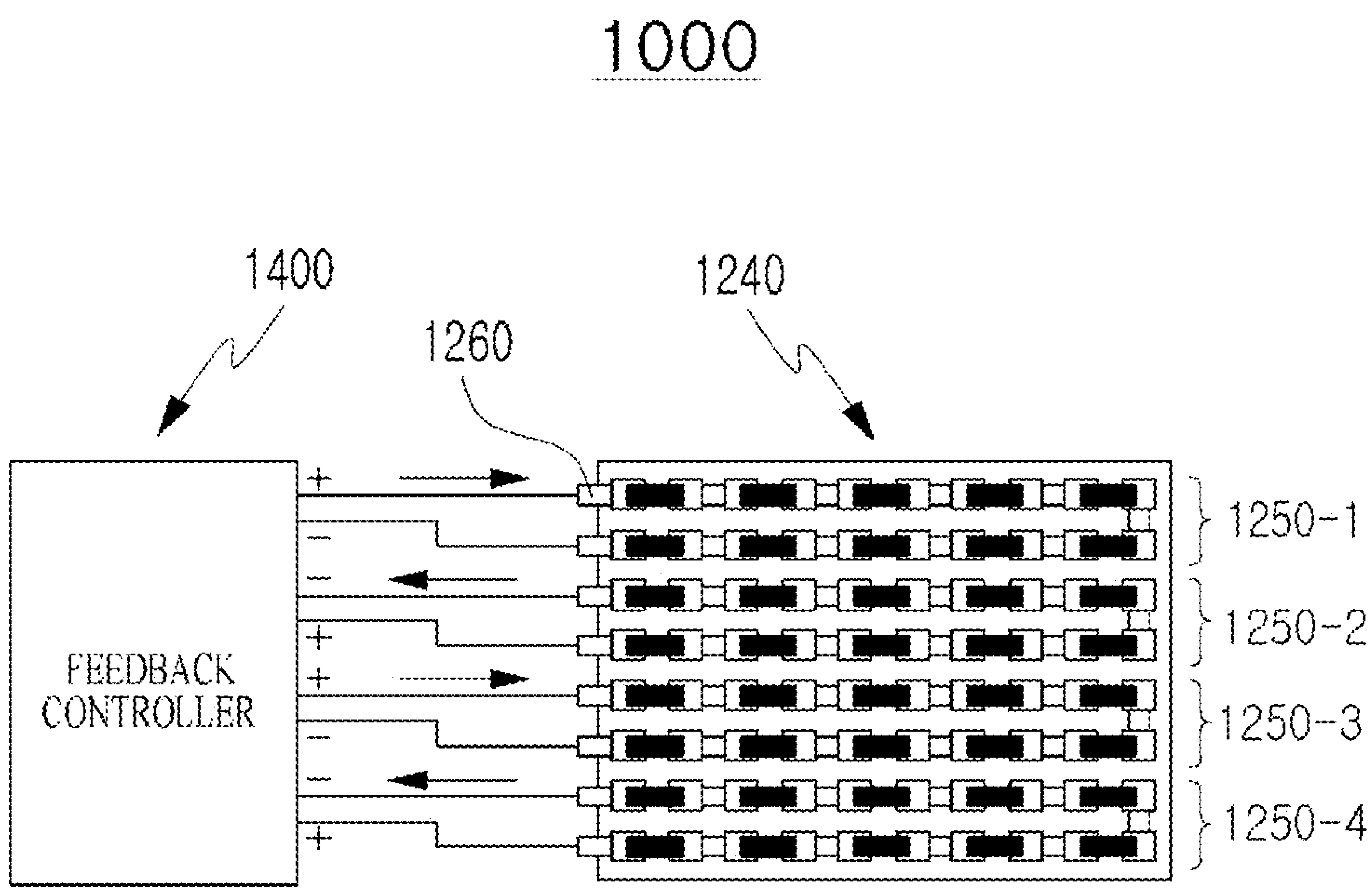

1000
1400
1260
1240
FEEDBACK CONTROLLER
+
−
−
+
+
−
−
+
1250-1
1250-2
1250-3
1250-4

FIG. 26

GRADE	FORWARD VOLTAGE	HOT FEEDBACK SATURATION TEMPERATURE	FORWARD VOLTAGE	HOT FEEDBACK SATURATION TEMPERATURE
1	V1+	ΔT1+	V1+	ΔT1−=−ΔT1+
2	V2+	ΔT2+=2ΔT1+	V2+	ΔT2−=−2ΔT1+
3	V3+	ΔT3+=3ΔT1+	V3+	ΔT3−=−3ΔT1+
4	V4+	ΔT4+=4ΔT1+	V4+	ΔT4−=−4ΔT1+
5	V5+	ΔT5+=5ΔT1+	V5+	ΔT5−=−5ΔT1+

NEUTRAL PROPORTION	VOLTAGE APPLIED TO FIRST THERMOELEMENT	VOLTAGE APPLIED TO SECOND THERMOELEMENT
2	V1+, V2+	V2−, V4−
2.5	V2+	V5−
3	V1+	V3−
4	V1+	V4−
5	V1+	V5−

FIG. 27

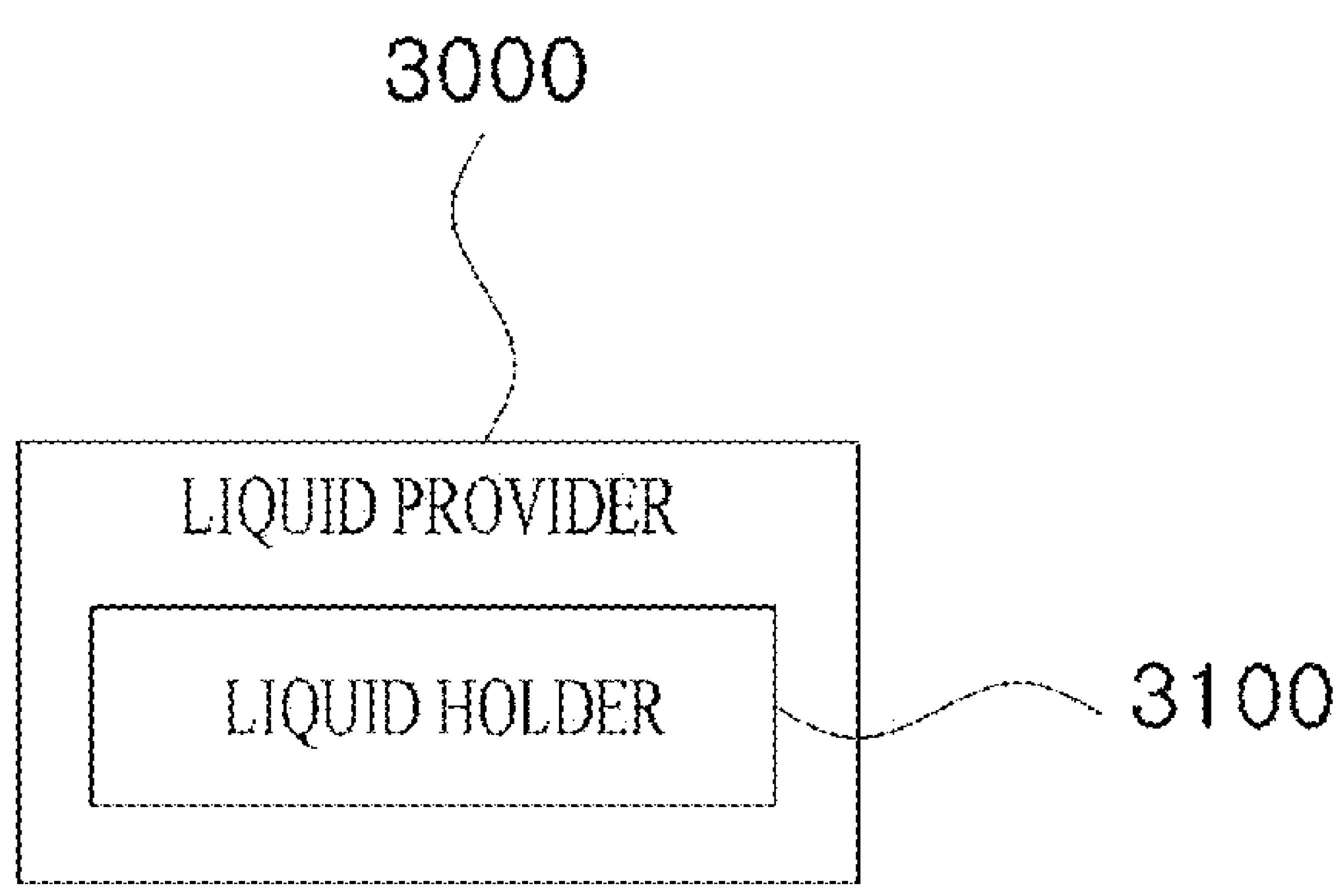


FIG. 28

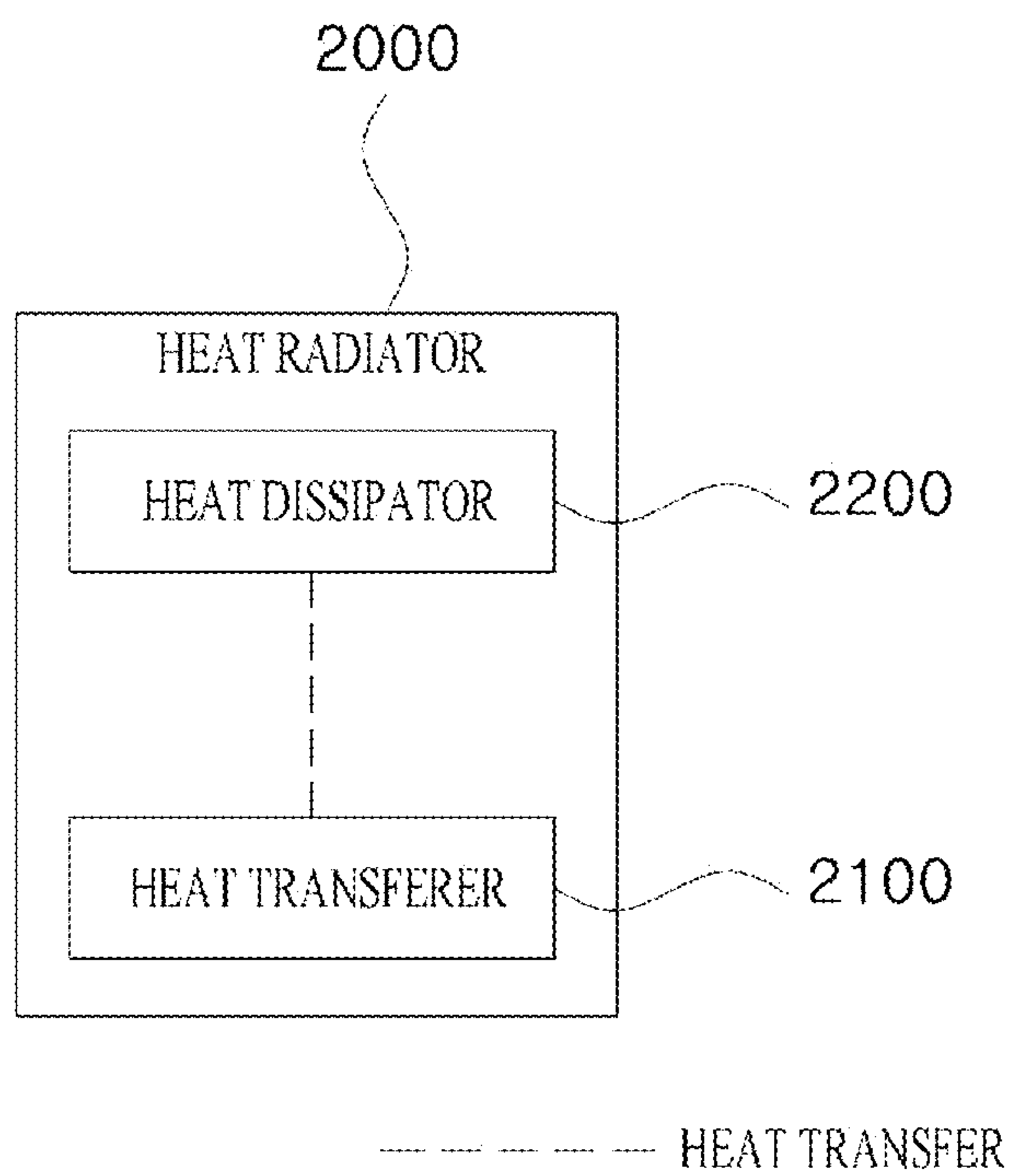

2000
HEAT RADIATOR
HEAT DISSIPATOR
2200
HEAT TRANSFERER
2100
HEAT TRANSFER

FIG. 29

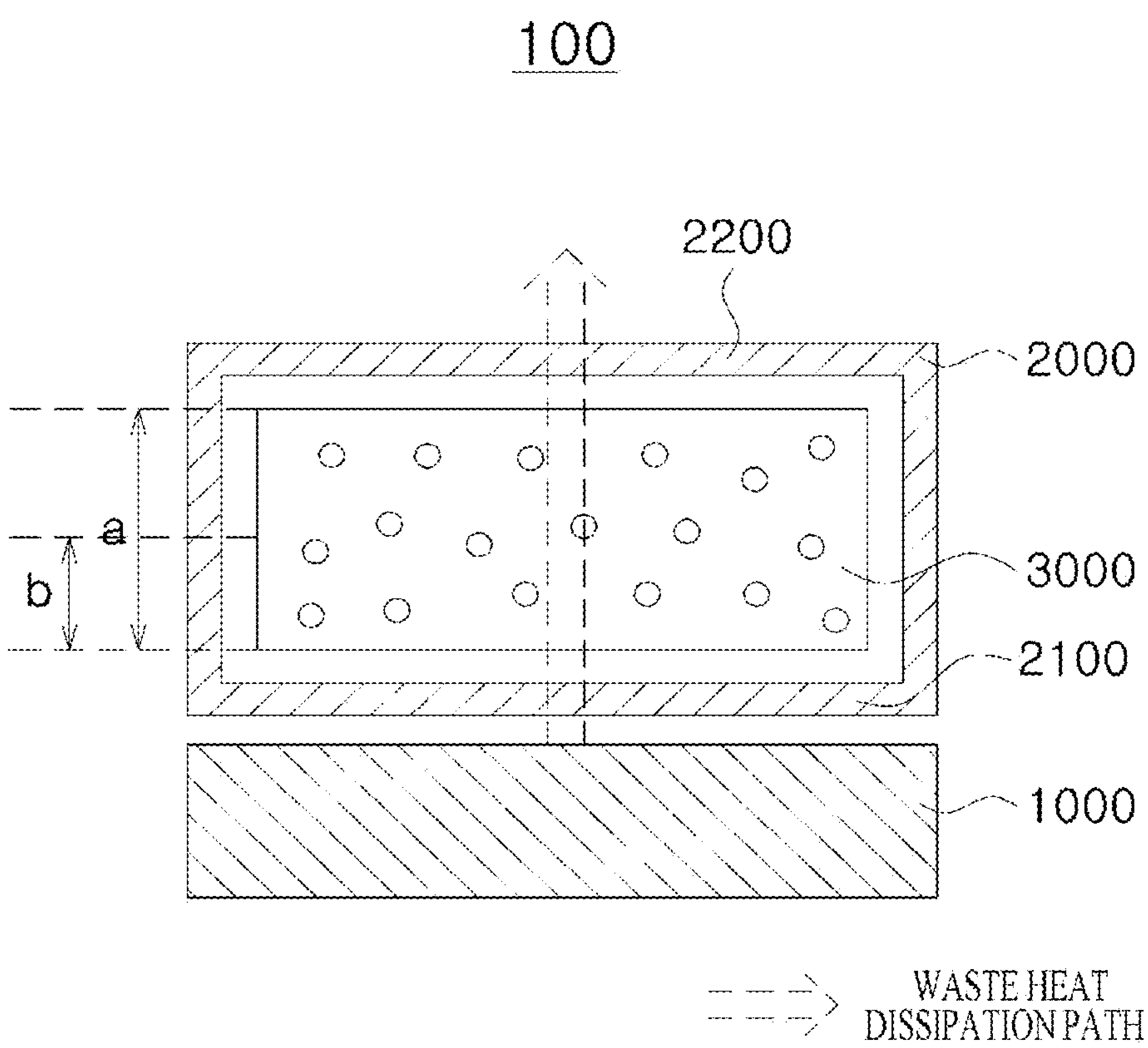


FIG. 30

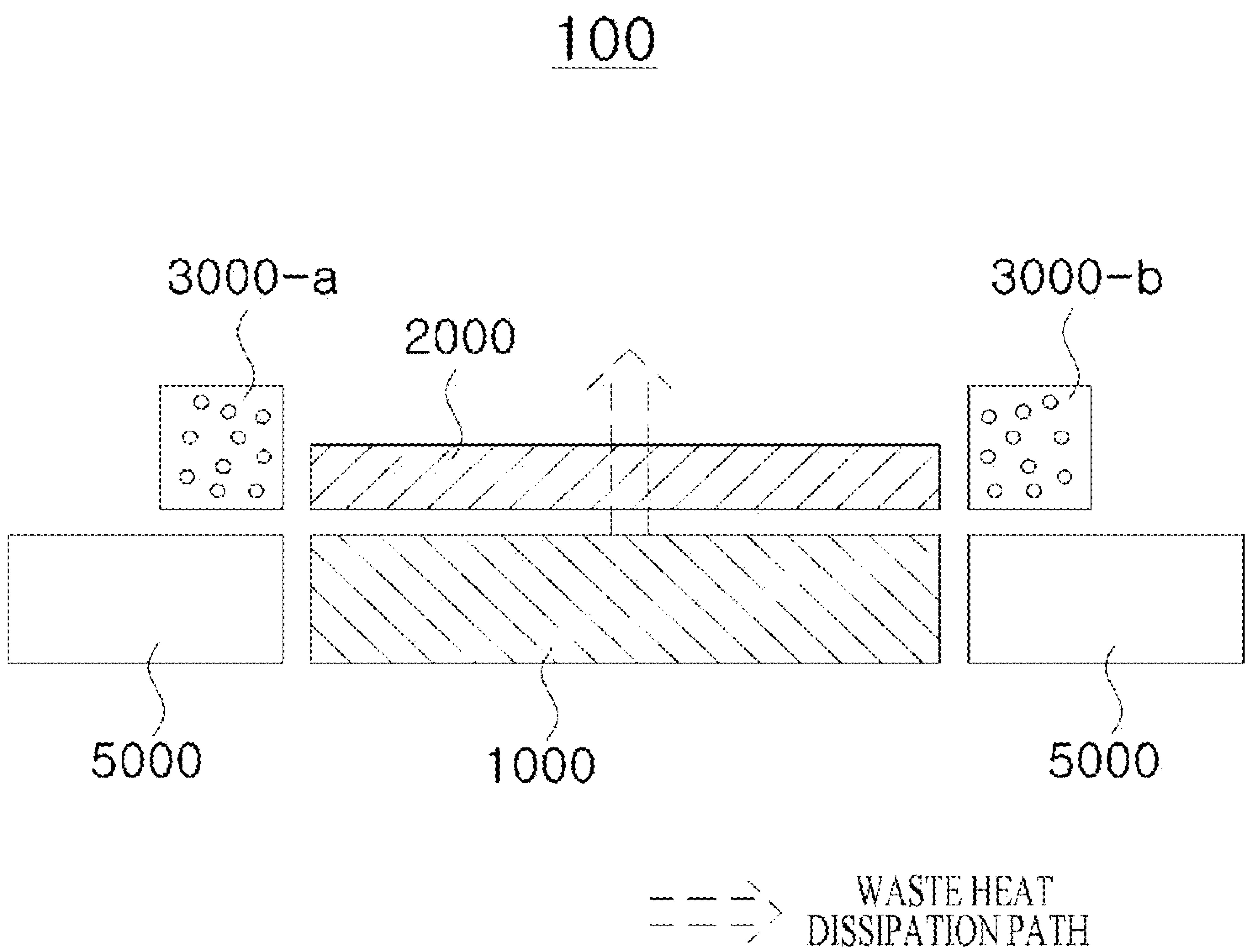

100
3000-a
2000
3000-b
5000
1000
5000
WASTE HEAT
DISSIPATION PATH

FIG. 31

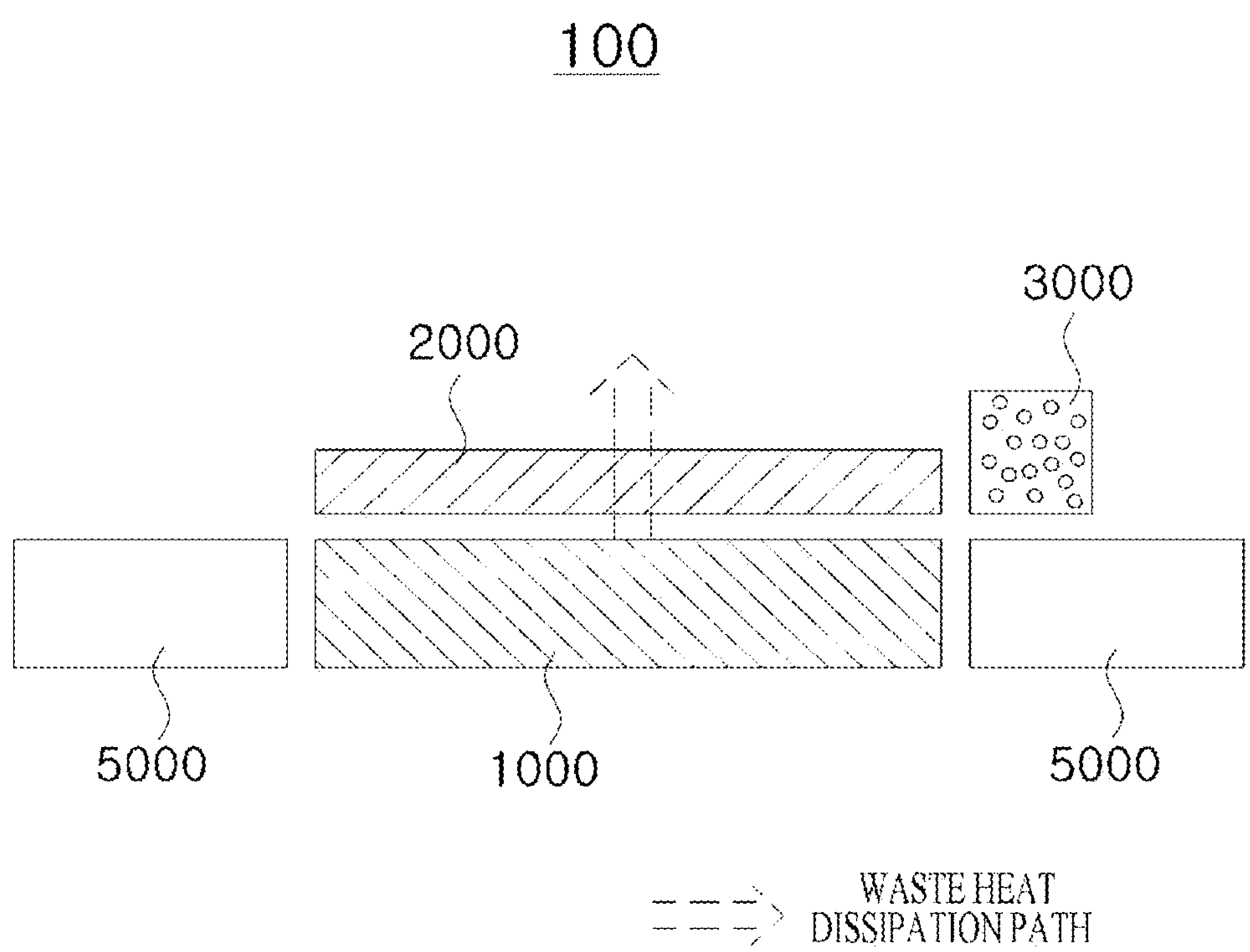


FIG. 32

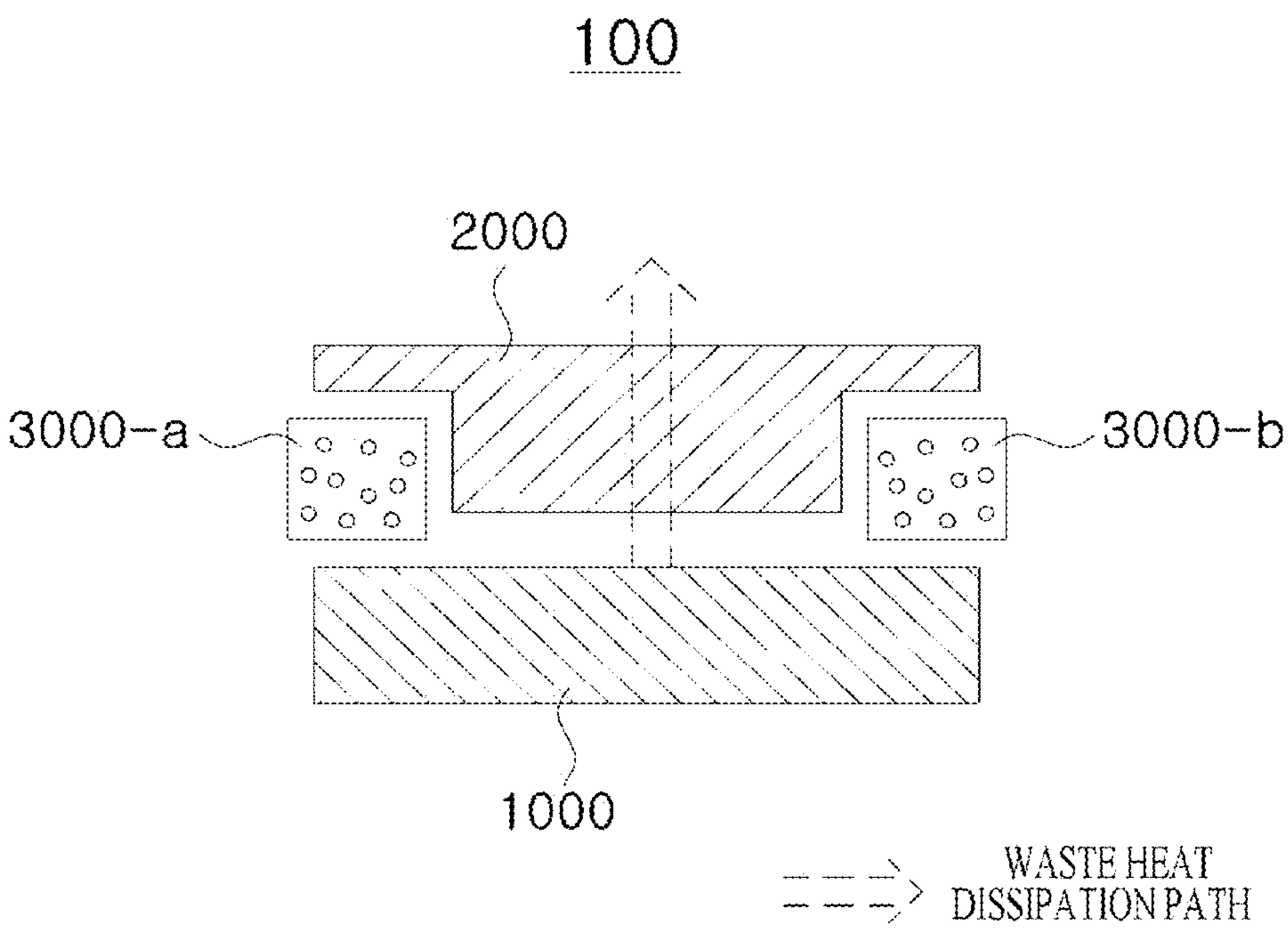


FIG. 33

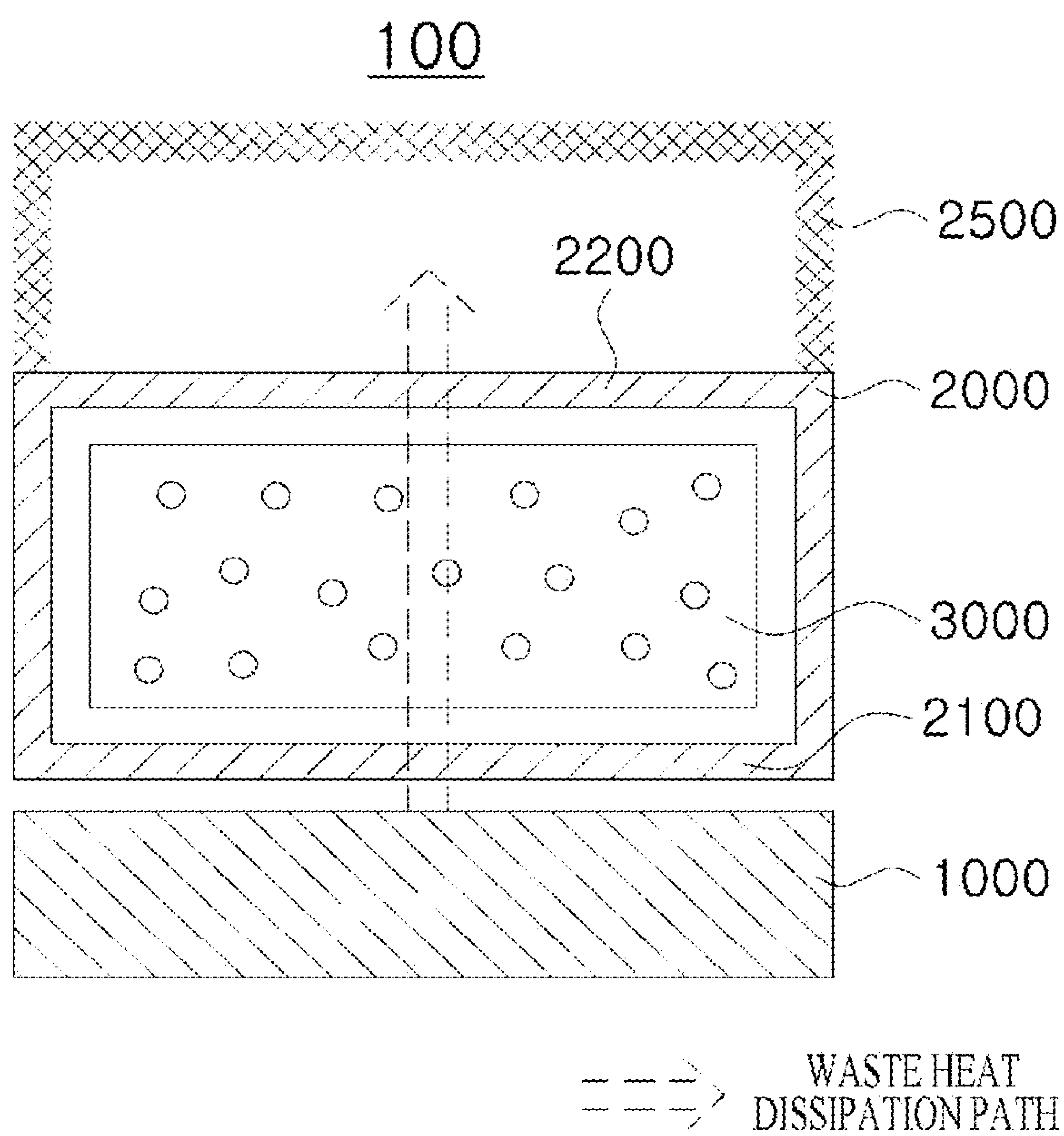

100
2500
2200
2000
3000
2100
1000
WASTE HEAT
DISSIPATION PATH

FIG. 34

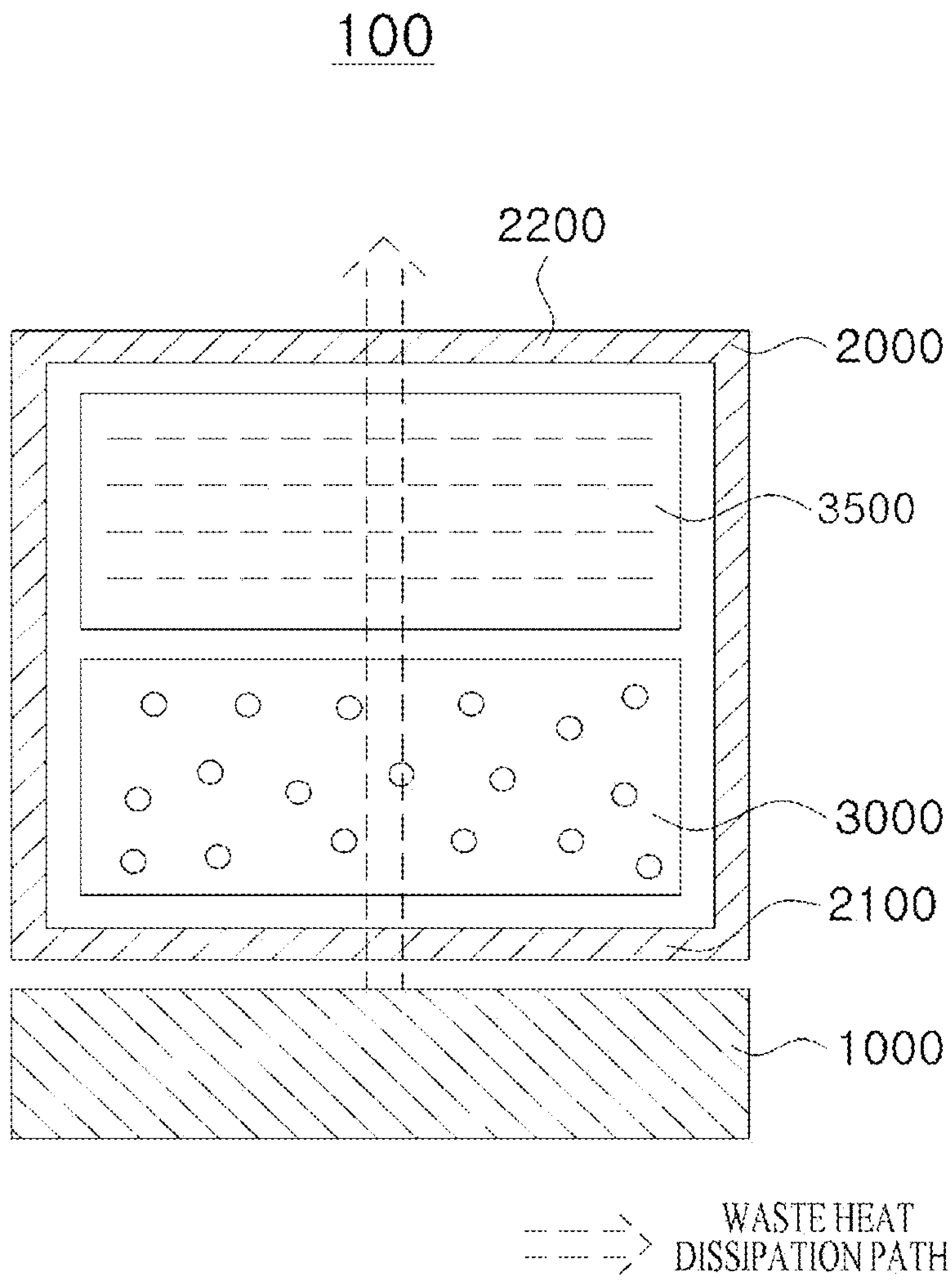

100
2200
2000
3500
3000
2100
1000
WASTE HEAT
DISSIPATION PATH

FIG. 35

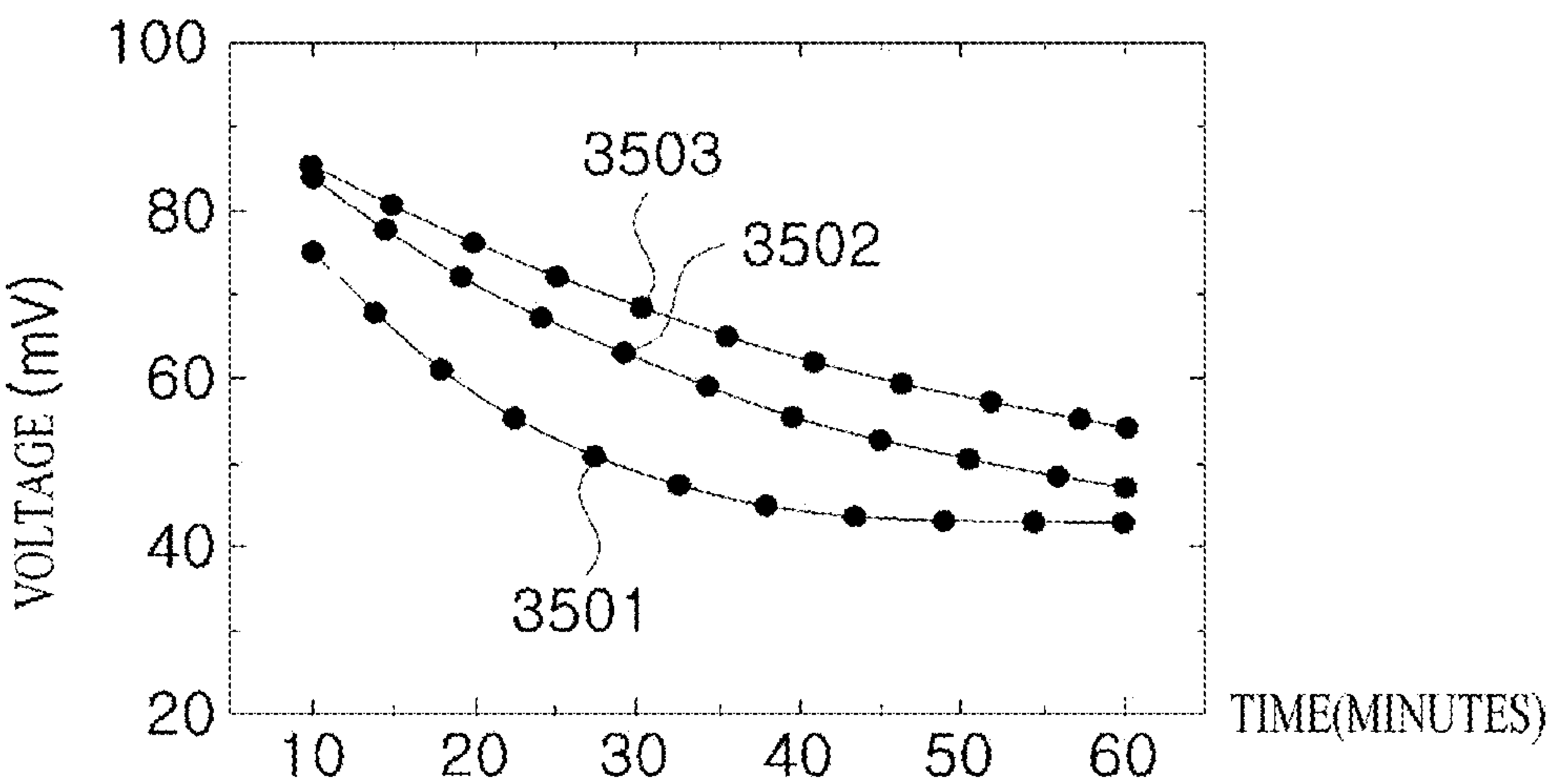
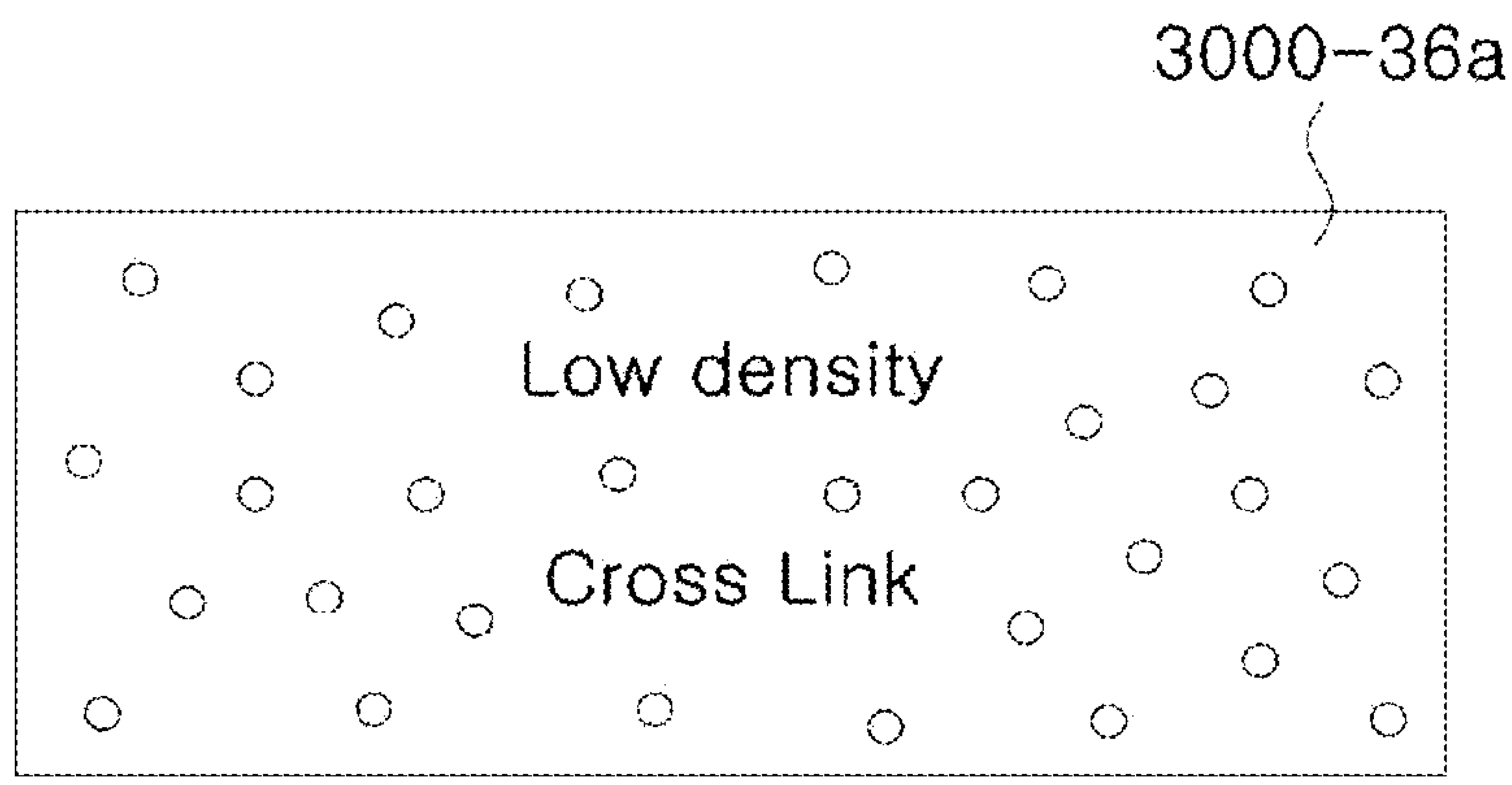
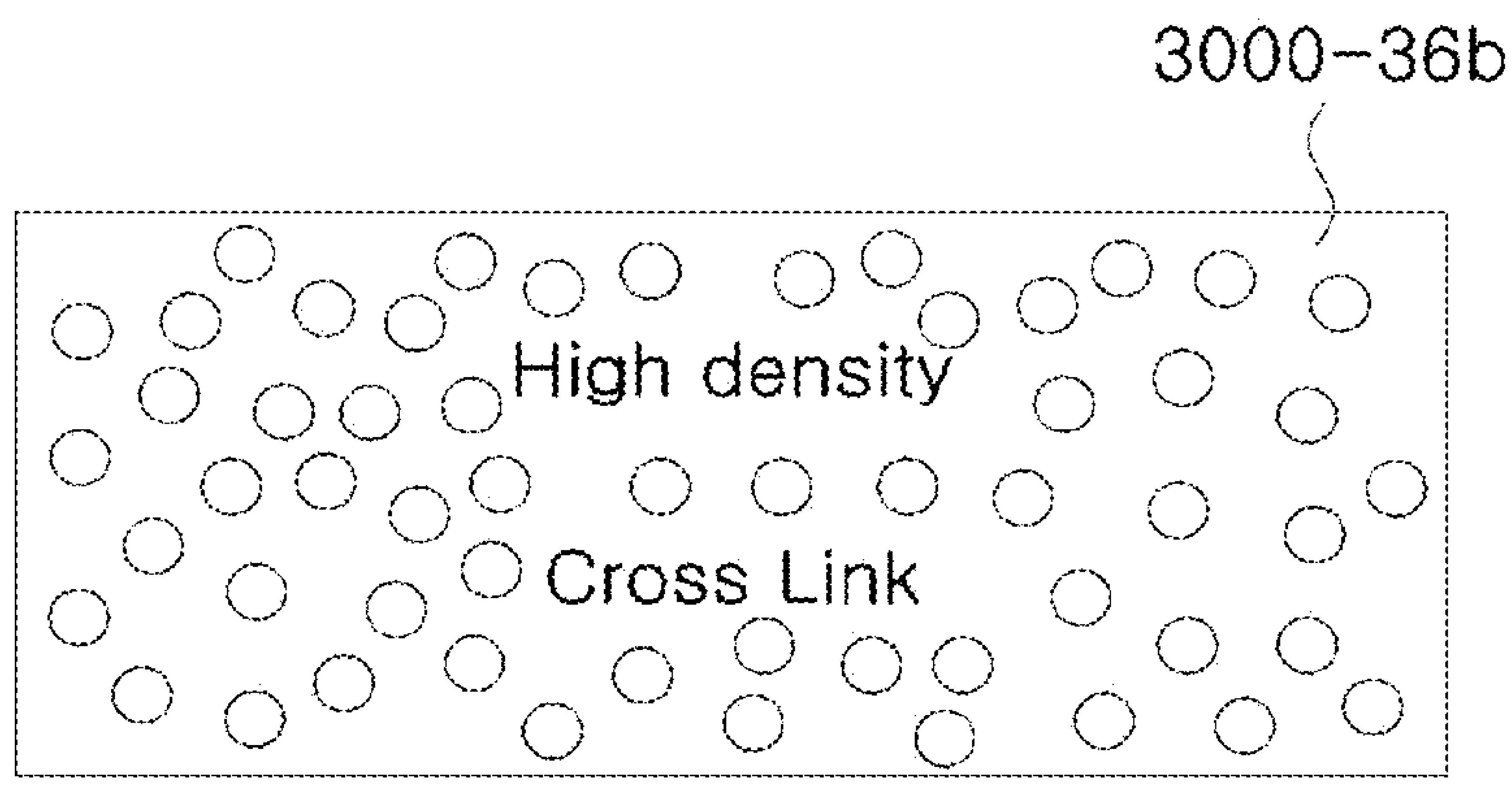

100
80
60
40
20
VOLTAGE (mV)
3503
3502
3501
10
20
30
40
50
60
TIME(MINUTES)

FIG. 36

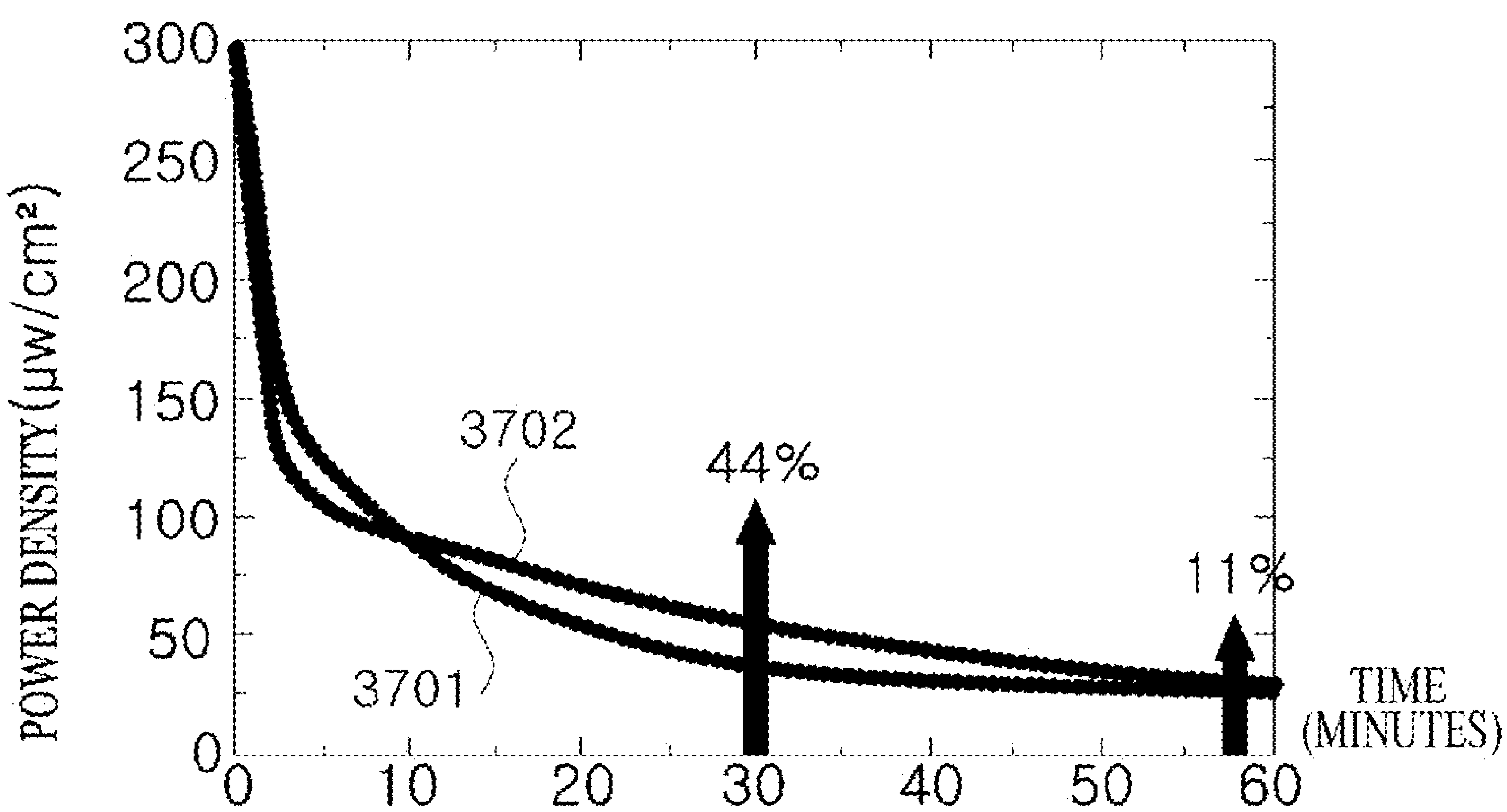

3000-36a
Low density
Cross Link

(a)


3000-36b
High density
Cross Link

(b)

FIG. 37



(a)

	High density			Low density		
TIME(MINUTES)	10	30	60	10	30	60
POWER DENSITY(μw/cm²)	90.7	37.7	25.9	90.7	54.1	28.8

(b)

FIG. 38

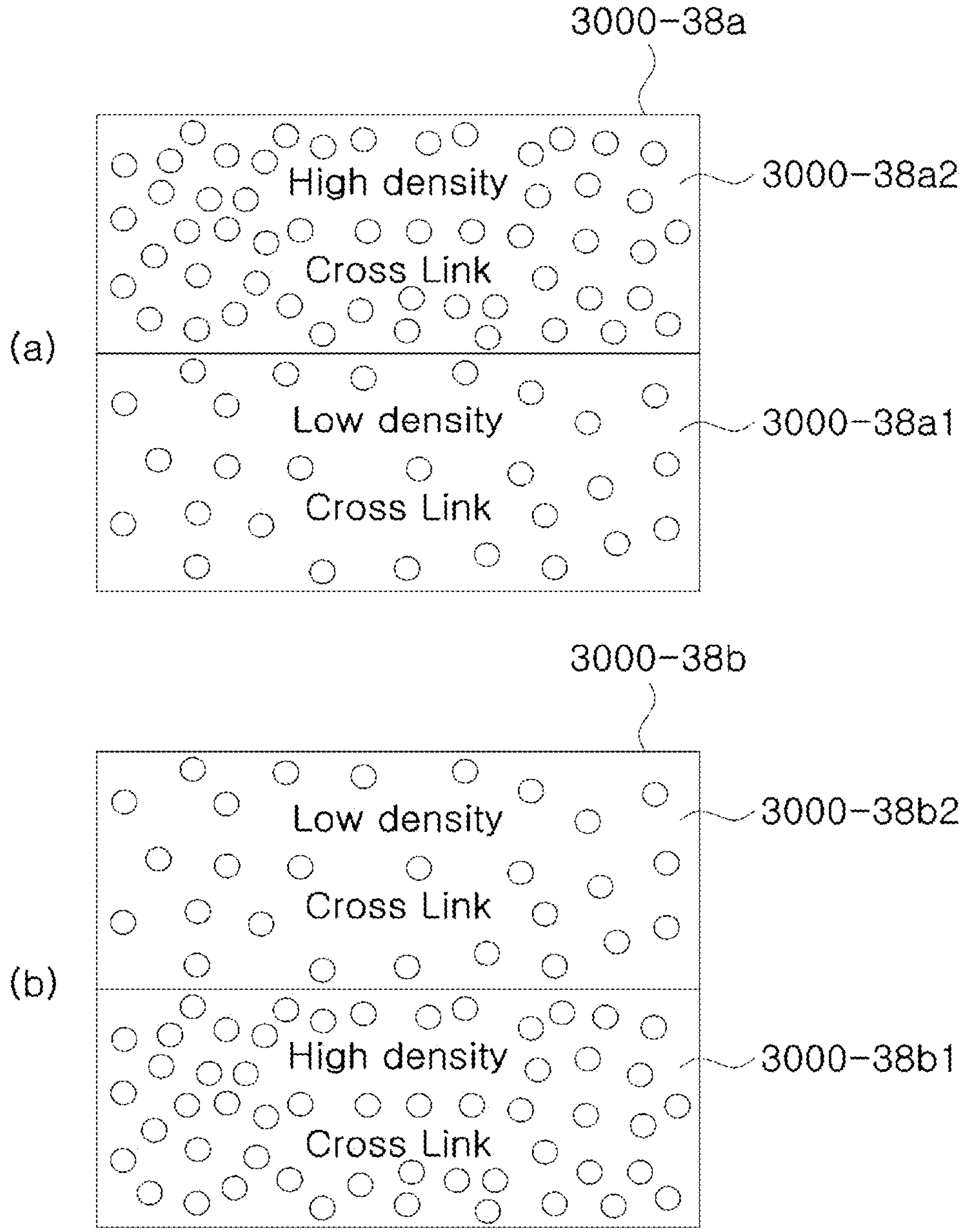

3000-38a
3000-38a2
High density
Cross Link
(a)
Low density
Cross Link
3000-38a1
3000-38b
3000-38b2
Low density
Cross Link
(b)
High density
Cross Link
3000-38b1

FIG.39

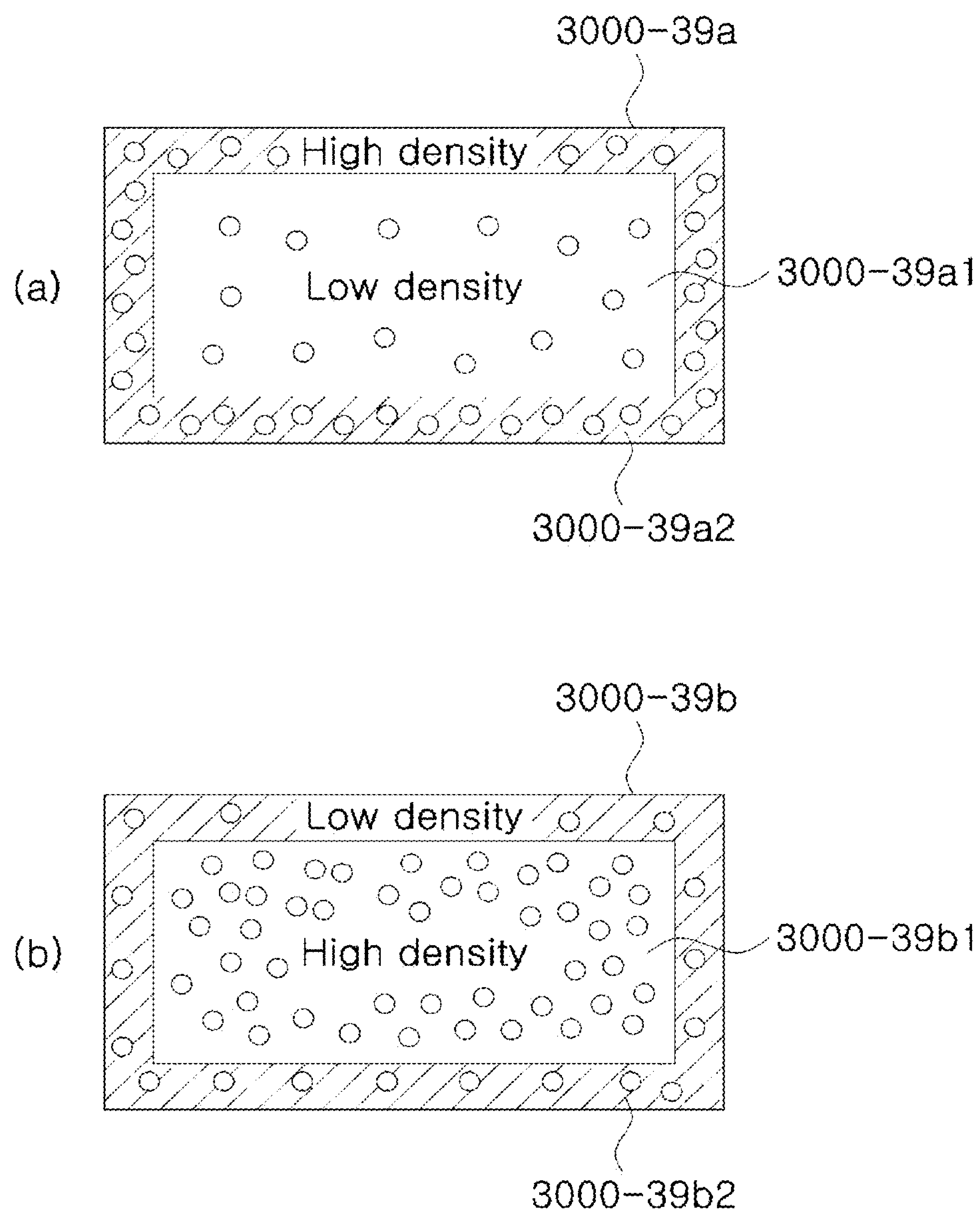

3000-39a
High density
Low density
(a)
3000-39a1
3000-39a2
3000-39b
Low density
High density
(b)
3000-39b1
3000-39b2

FIG. 40

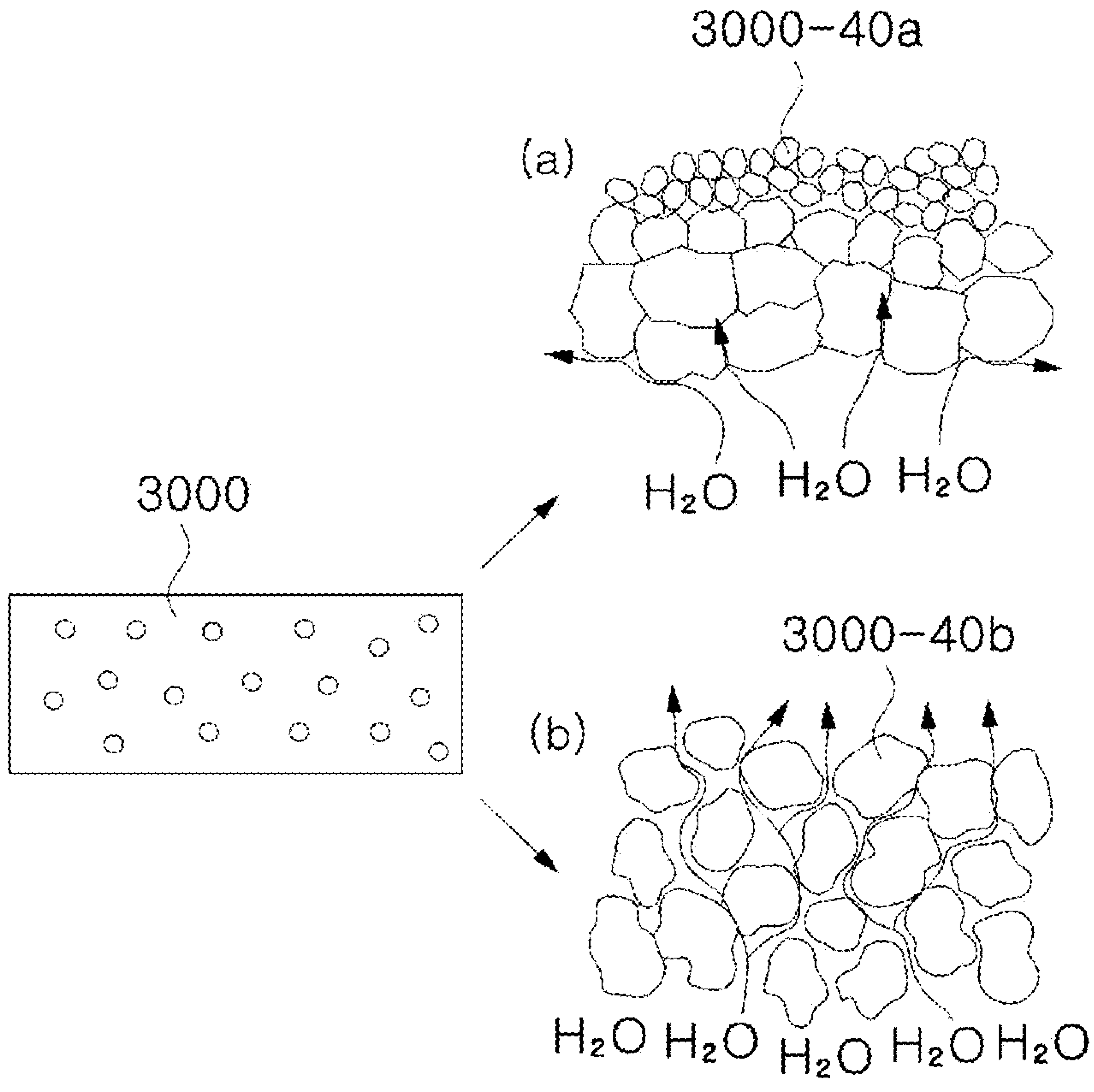


FIG. 41

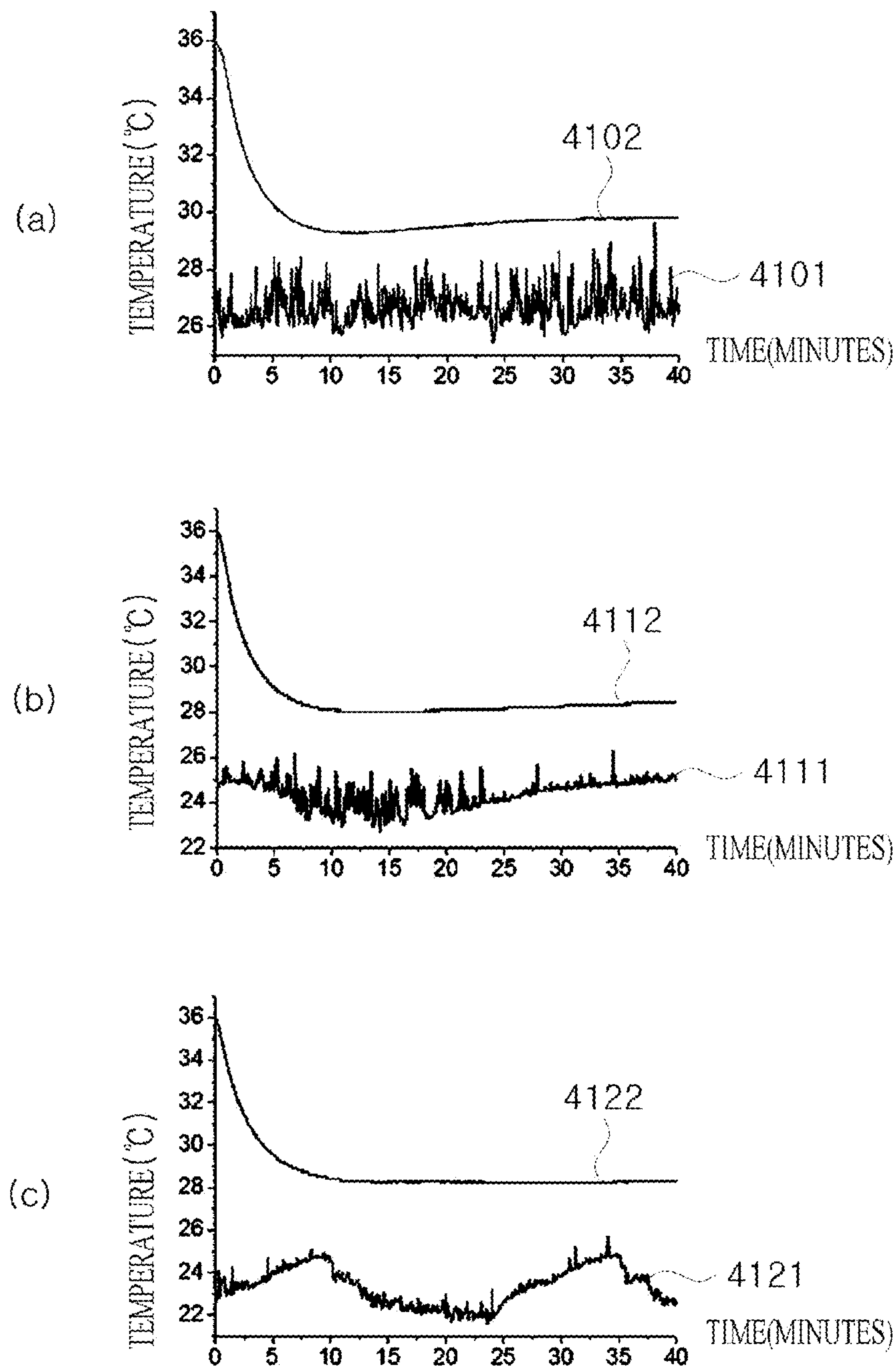
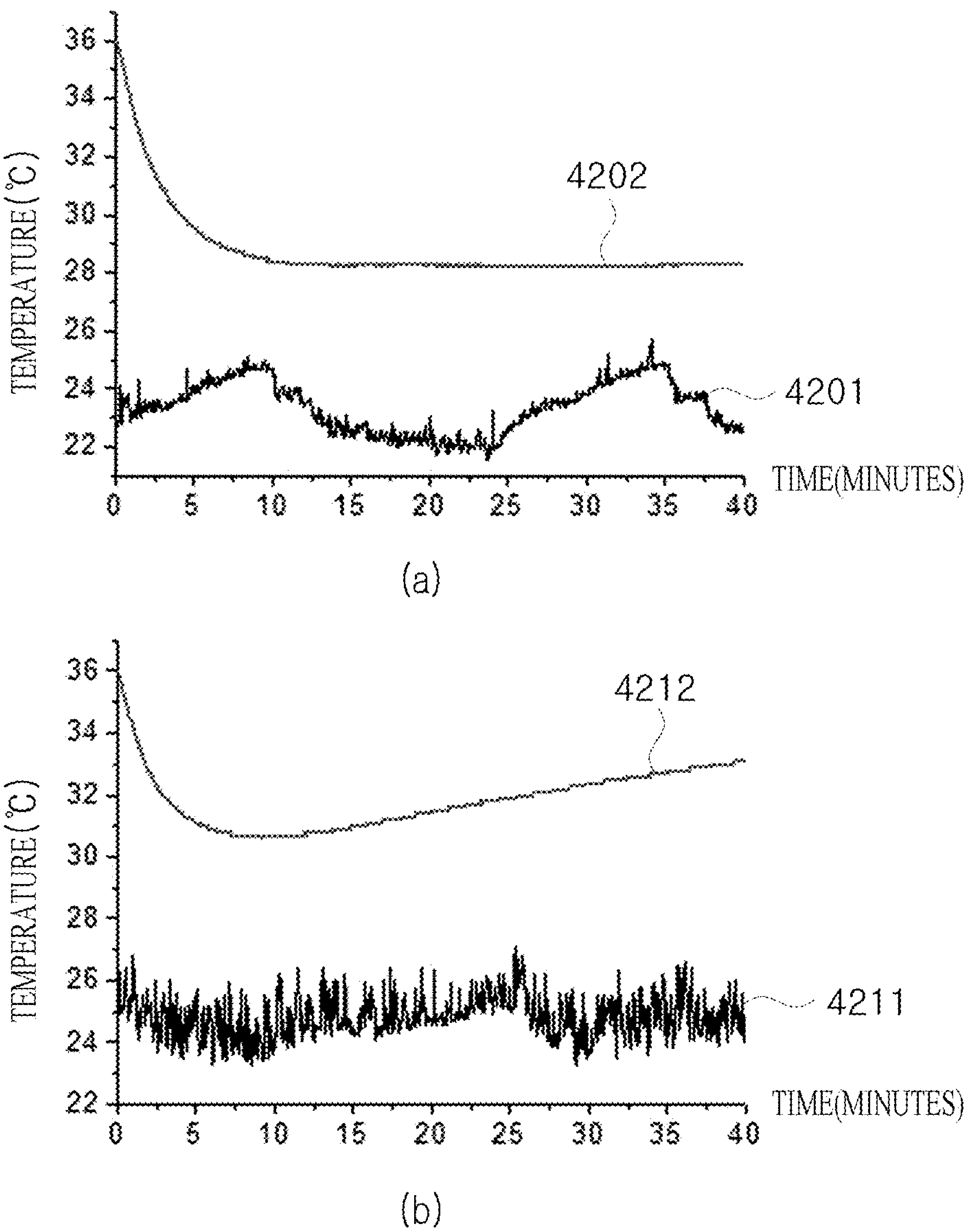

(a)
TEMPERATURE(℃)
36
34
32
30
28
26
4102
4101
TIME(MINUTES)
0 5 10 15 20 25 30 35 40
(b)
TEMPERATURE(℃)
36
34
32
30
28
26
24
22
4112
4111
TIME(MINUTES)
0 5 10 15 20 25 30 35 40
(c)
TEMPERATURE(℃)
36
34
32
30
28
26
24
22
4122
4121
TIME(MINUTES)
0 5 10 15 20 25 30 35 40

FIG. 42



TEMPERATURE(℃)
36
34
32
30
28
26
24
22
4202
4201
TIME(MINUTES)
0
5
10
15
20
25
30
35
40
(a)
TEMPERATURE(℃)
36
34
32
30
28
26
24
22
4212
4211
TIME(MINUTES)
0
5
10
15
20
25
30
35
40
(b)

FIG. 43

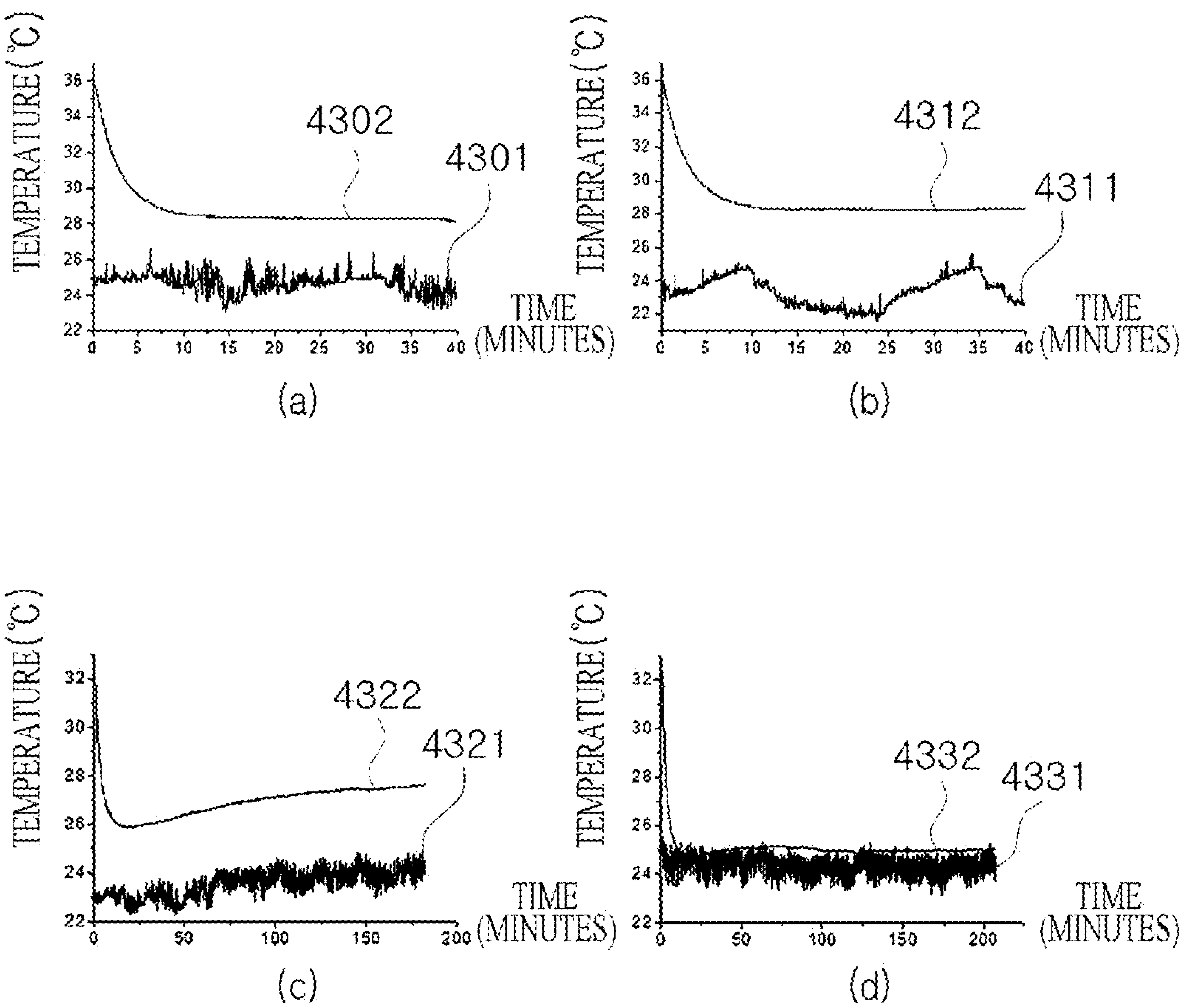

TEMPERATURE (°C)
4302
4301
TIME (MINUTES)
(a)
TEMPERATURE (°C)
4312
4311
TIME (MINUTES)
(b)
TEMPERATURE (°C)
4322
4321
TIME (MINUTES)
(c)
TEMPERATURE (°C)
4332
4331
TIME (MINUTES)
(d)

FIG. 44

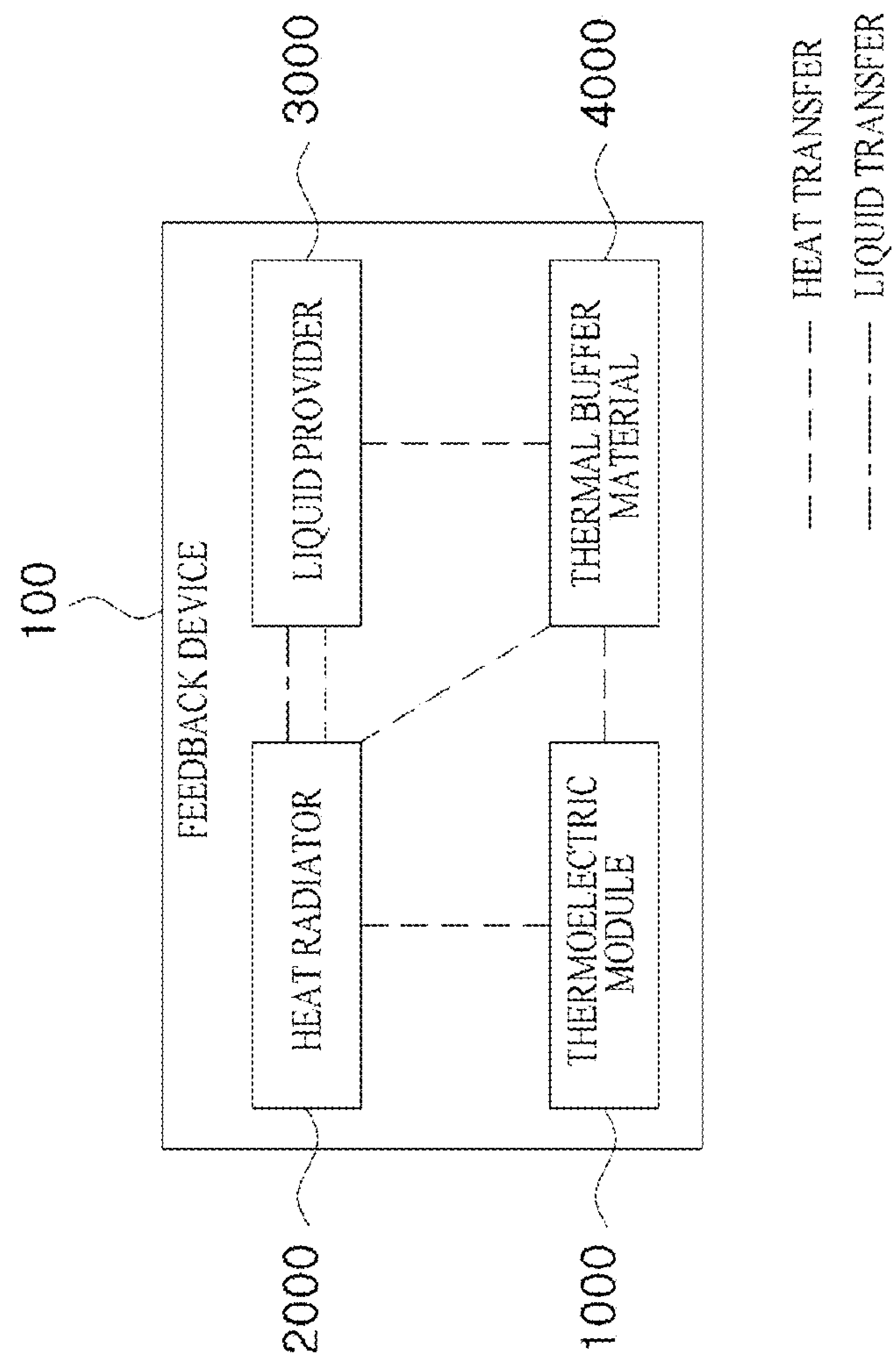

100
FEEDBACK DEVICE
LIQUID PROVIDER
3000
THERMAL BUFFER MATERIAL
4000
HEAT RADIATOR
2000
THERMOELECTRIC MODULE
1000
HEAT TRANSFER
LIQUID TRANSFER

FIG. 45

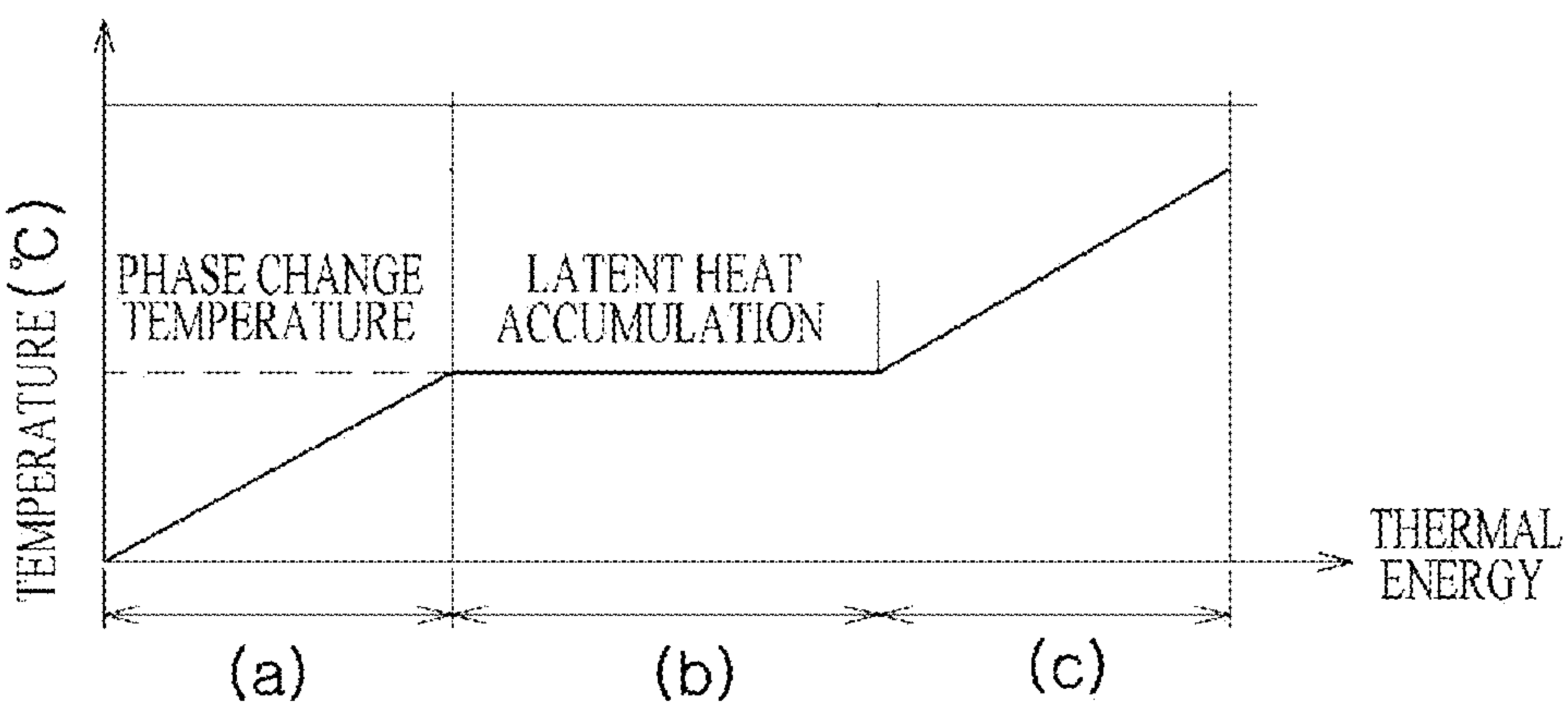

TEMPERATURE (℃)
PHASE CHANGE TEMPERATURE
LATENT HEAT ACCUMULATION
THERMAL ENERGY
(a)
(b)
(c)

FIG. 46

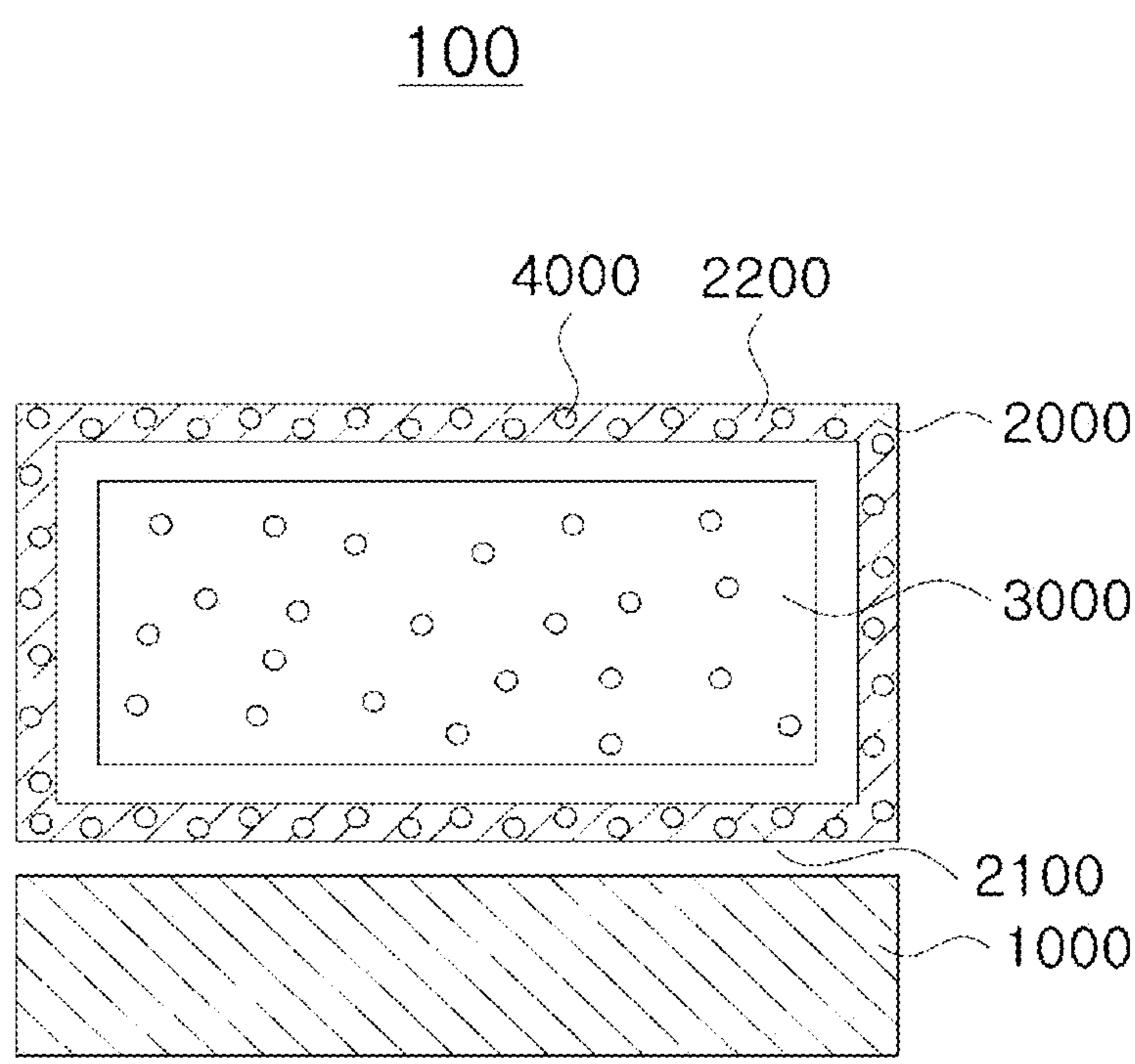


FIG. 47

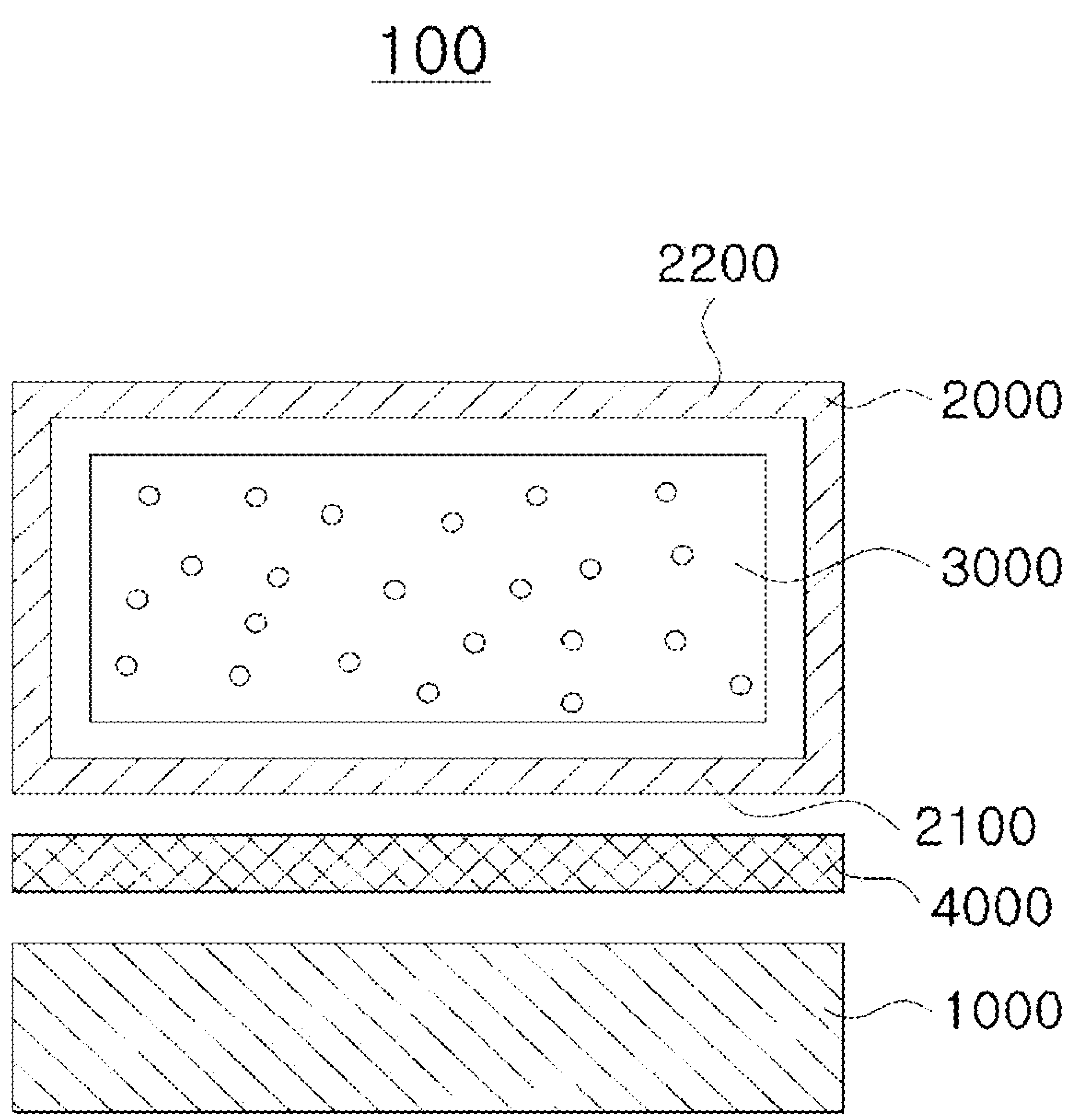


FIG. 48

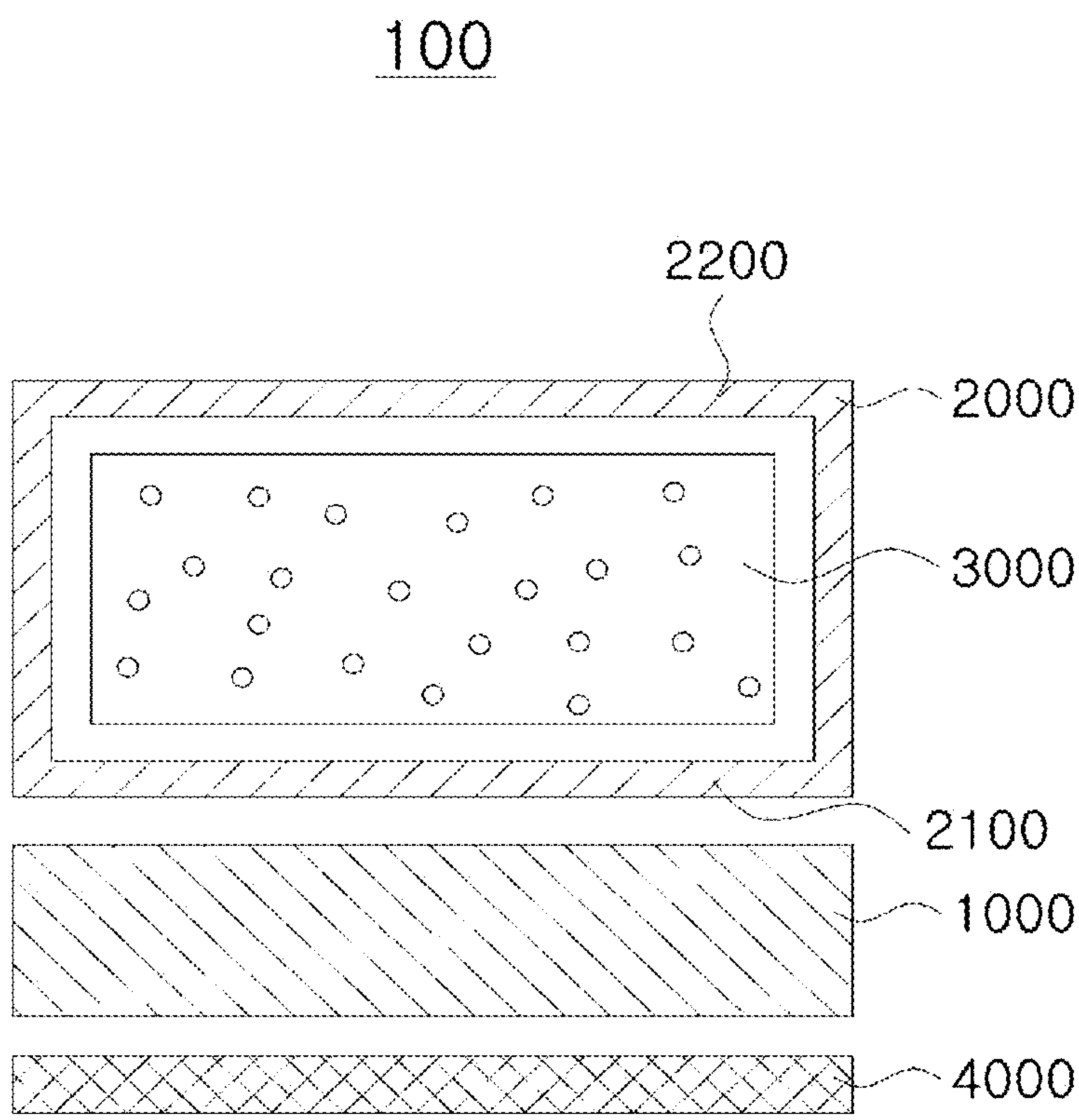


FIG. 49

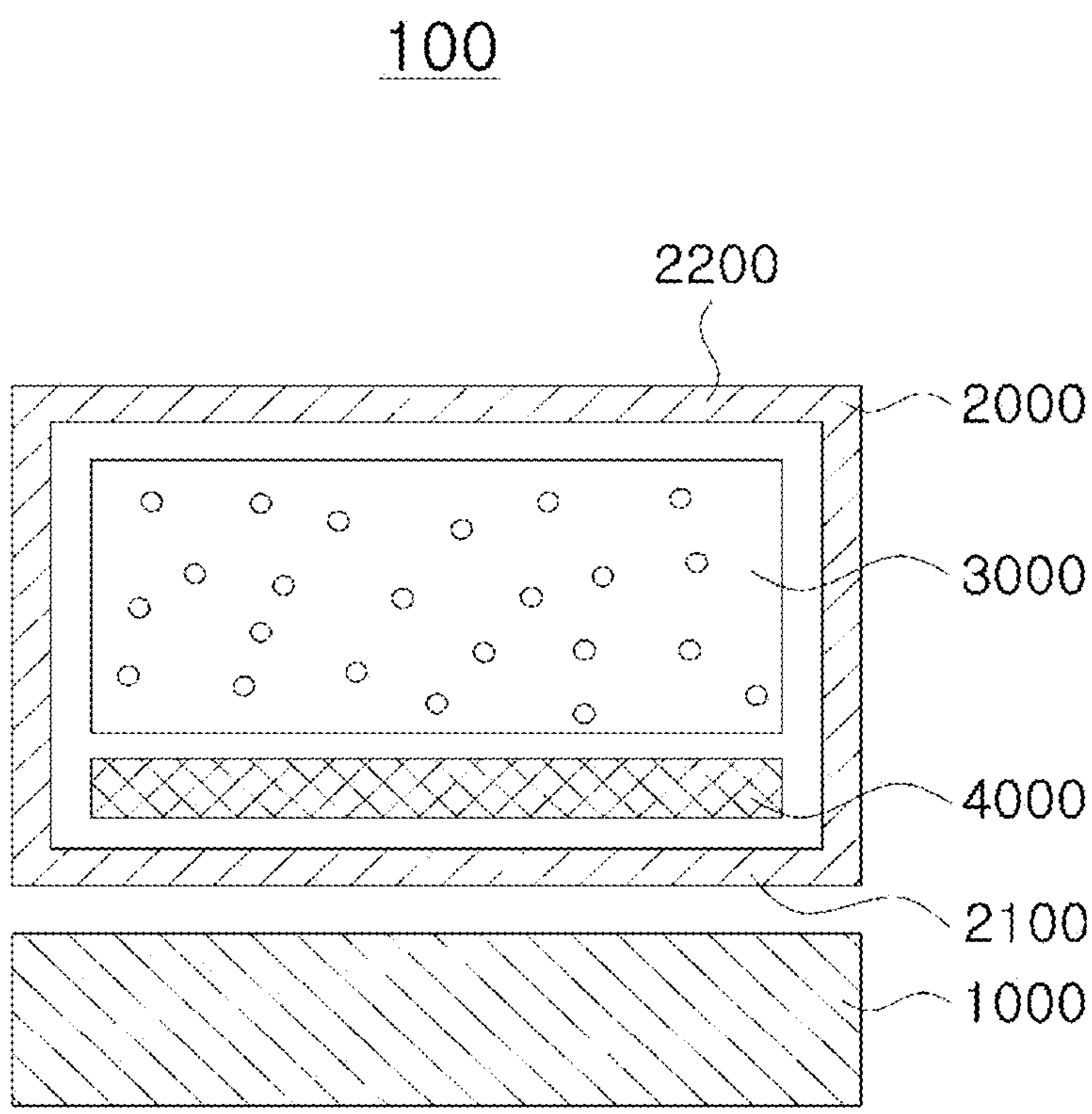


FIG. 50

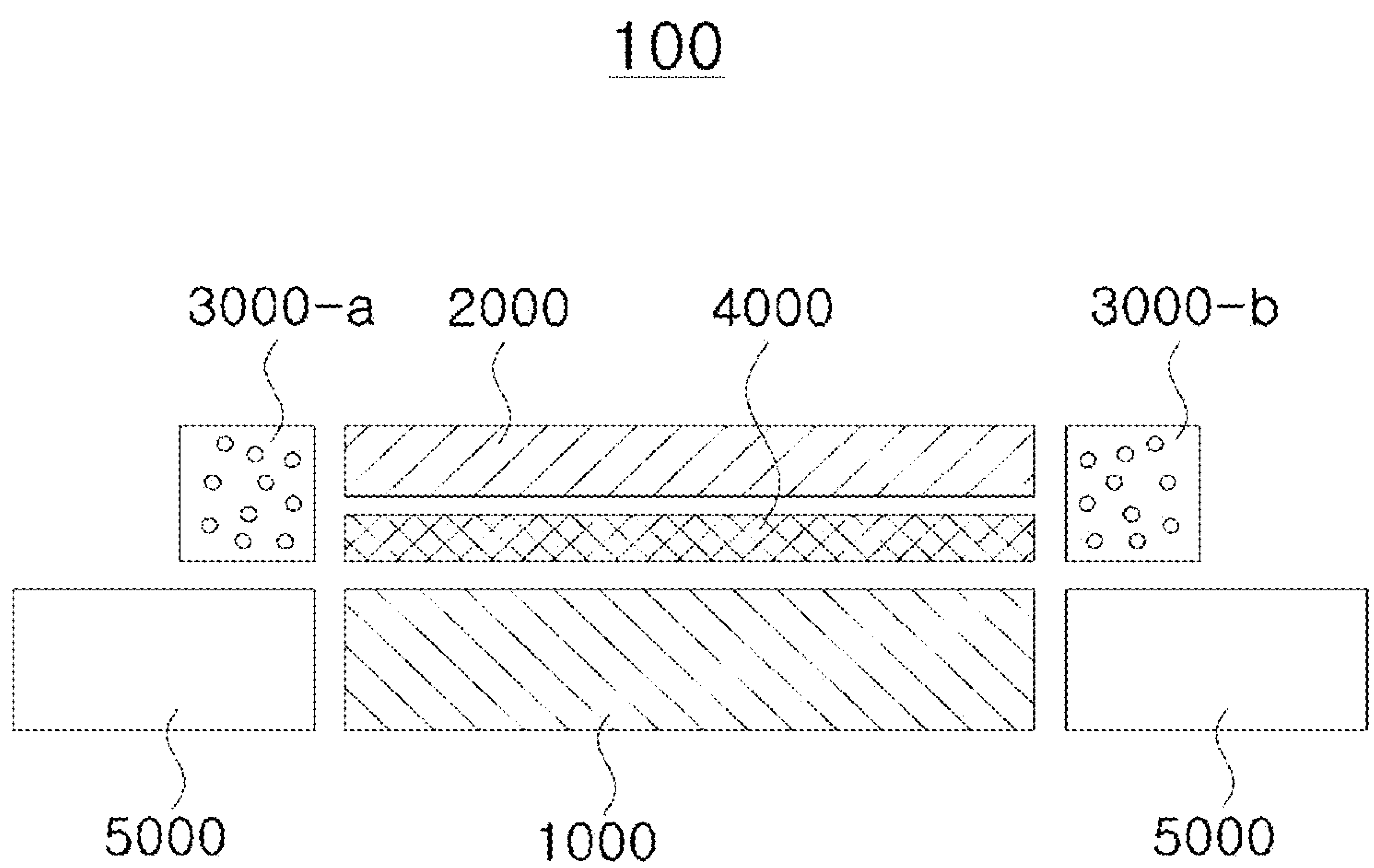


FIG. 51

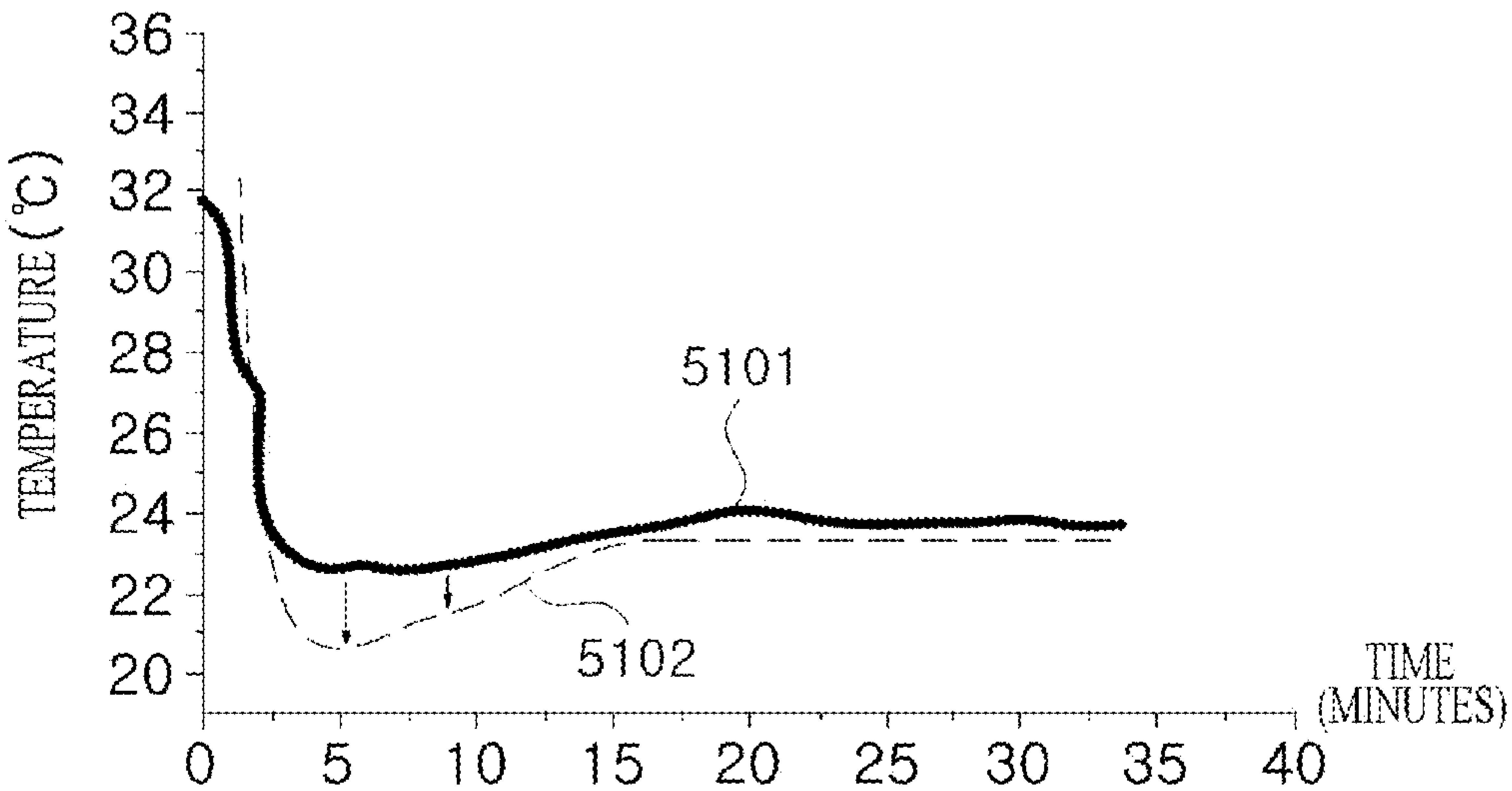
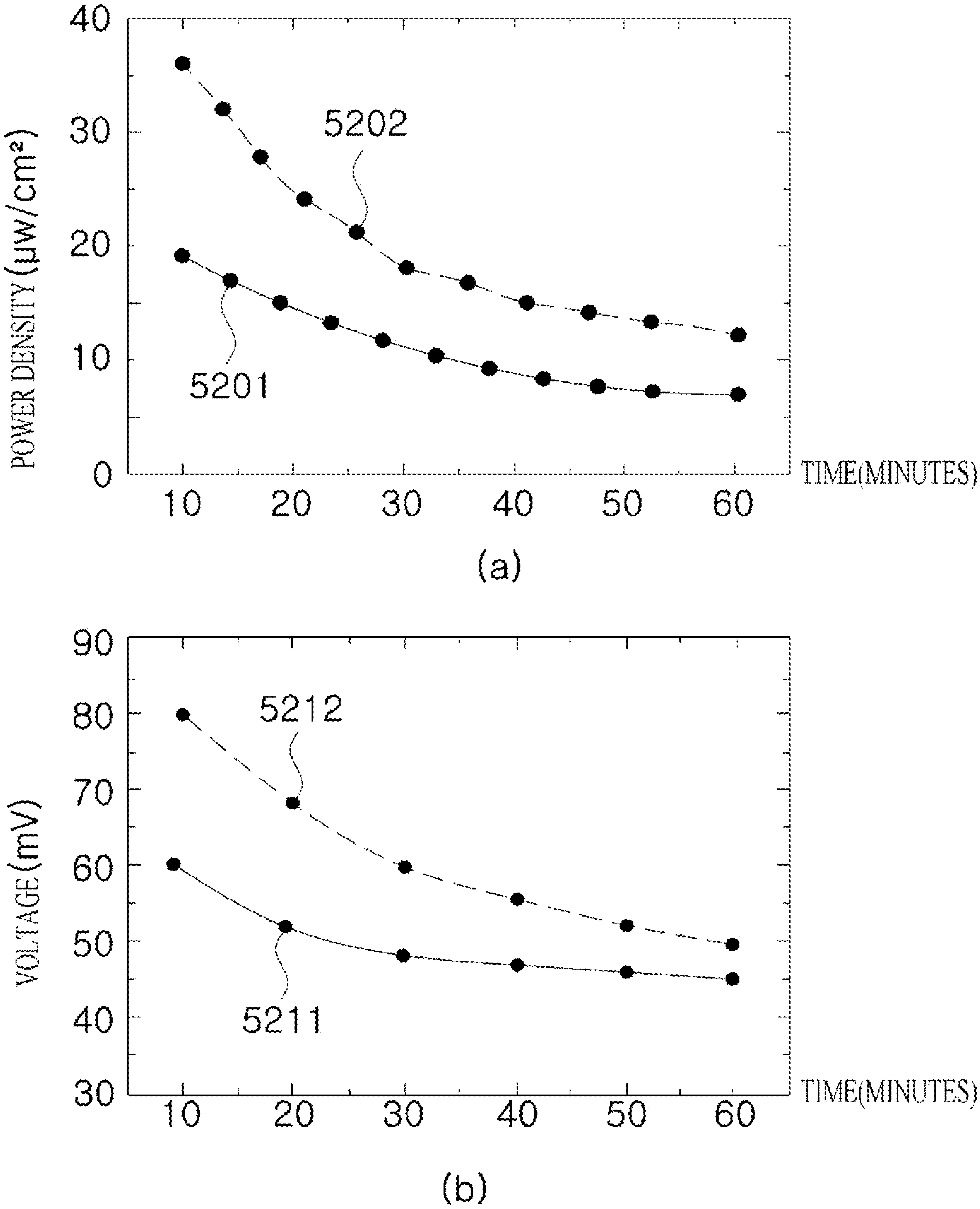
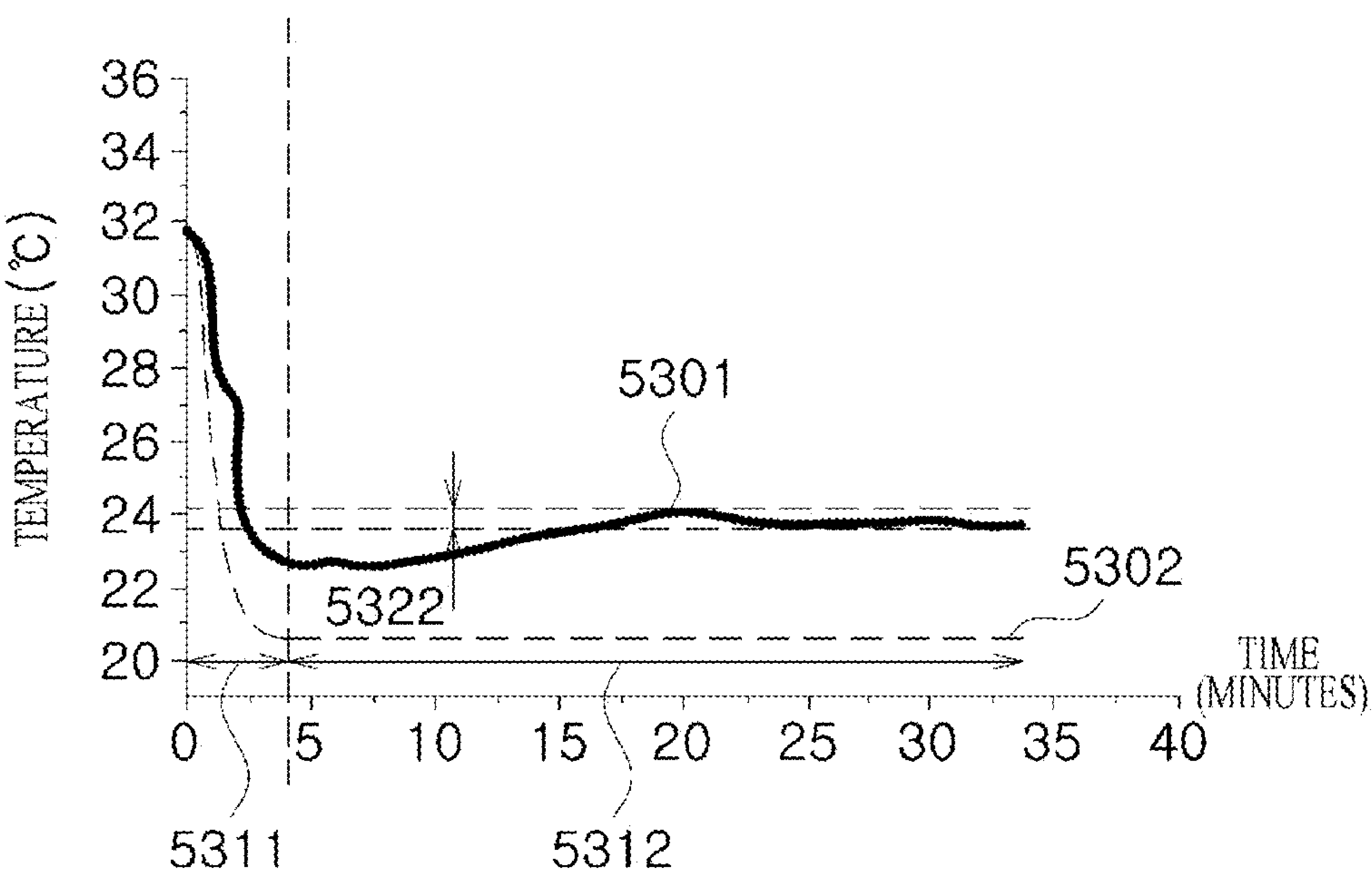

36
34
32
30
28
26
24
22
20
TEMPERATURE (℃)
5101
5102
0
5
10
15
20
25
30
35
40
TIME
(MINUTES)

FIG. 52



40
30
20
10
0
POWER DENSITY (μw/cm²)
5202
5201
10
20
30
40
50
60
TIME(MINUTES)
(a)
90
80
70
60
50
40
30
VOLTAGE (mV)
5212
5211
10
20
30
40
50
60
TIME(MINUTES)
(b)

FIG. 53



TEMPERATURE (℃)
36
34
32
30
28
26
24
22
20
5301
5302
5322
TIME (MINUTES)
0
5
10
15
20
25
30
35
40
5311
5312

FIG. 54

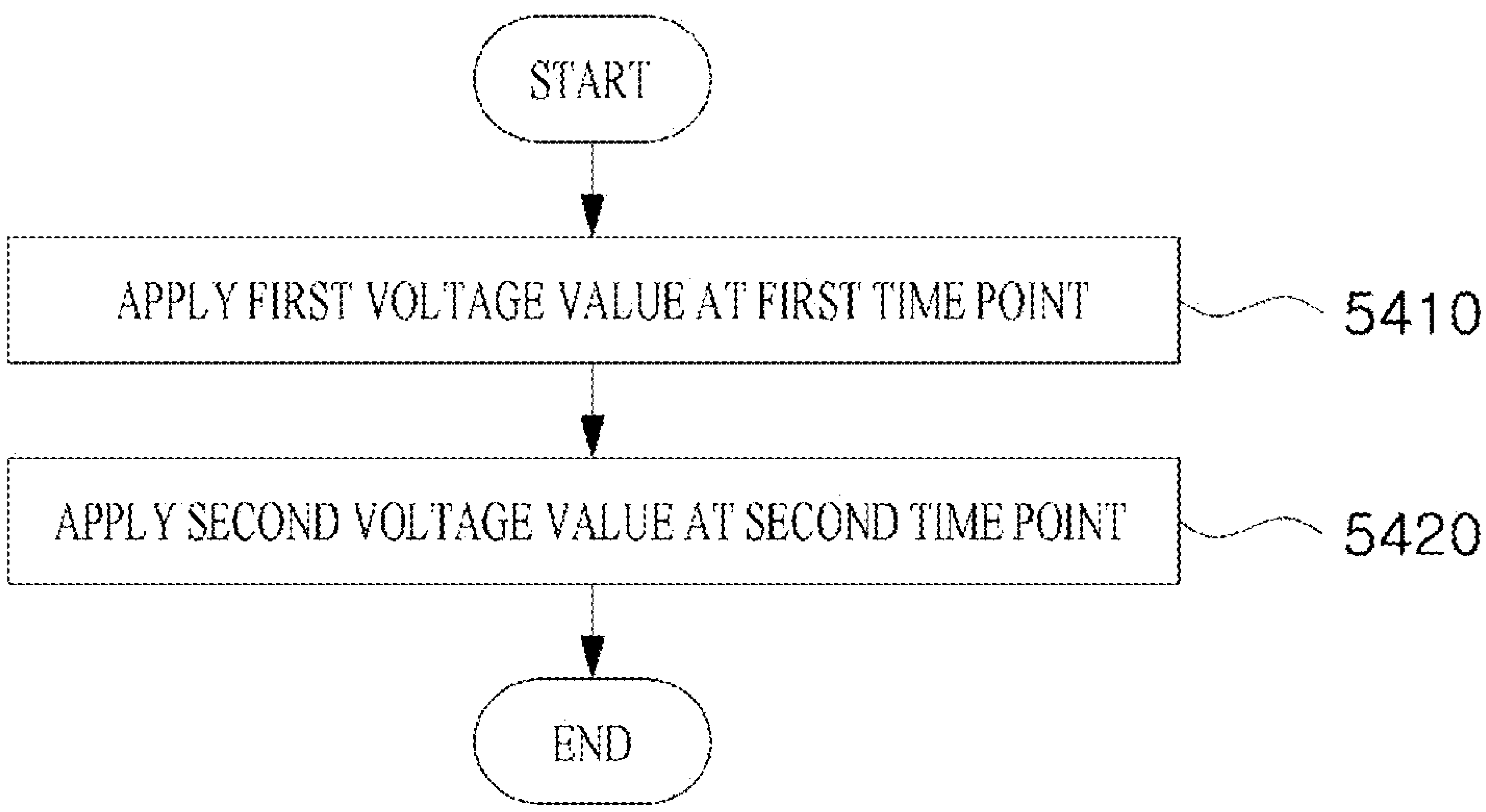
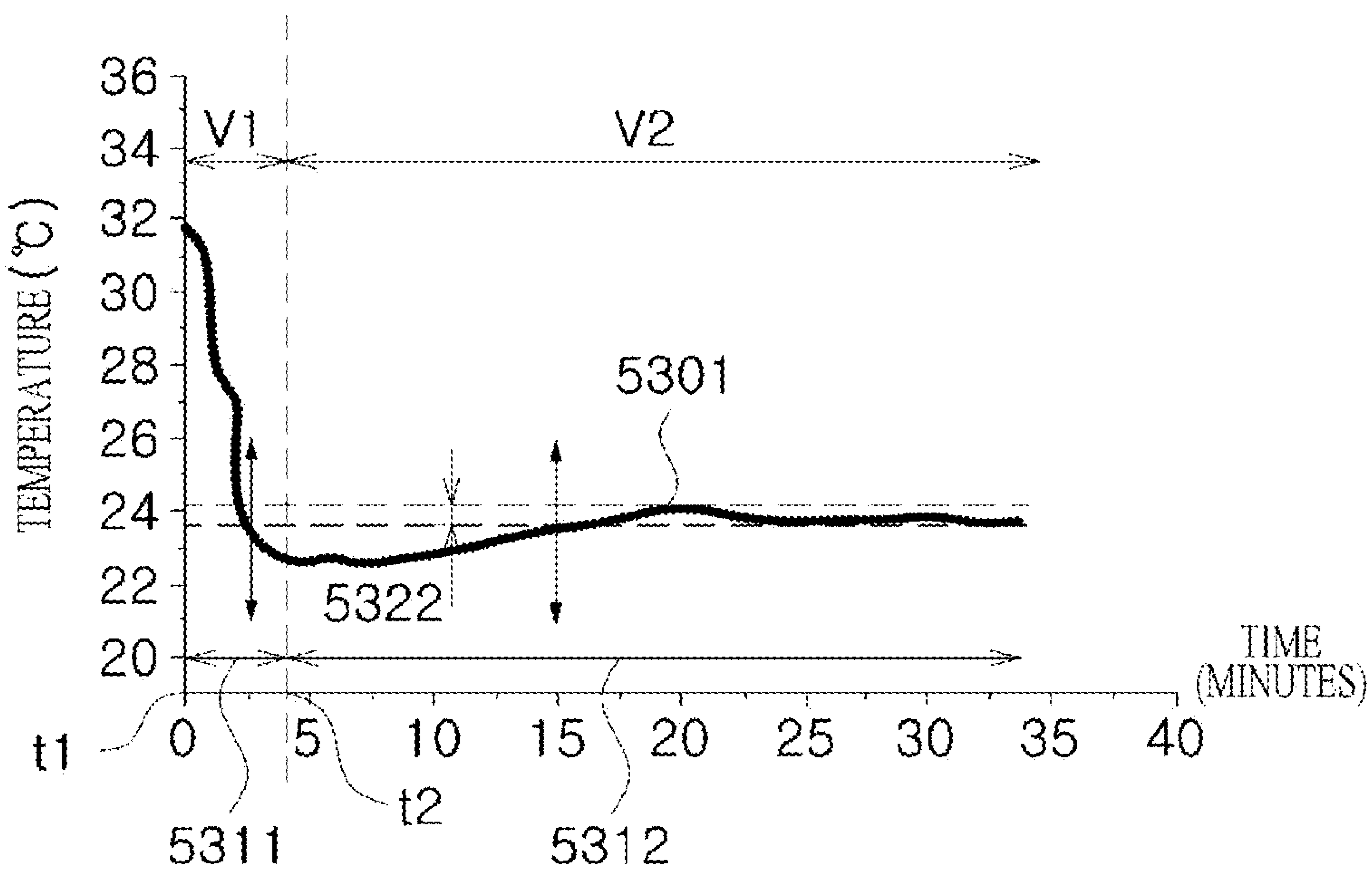
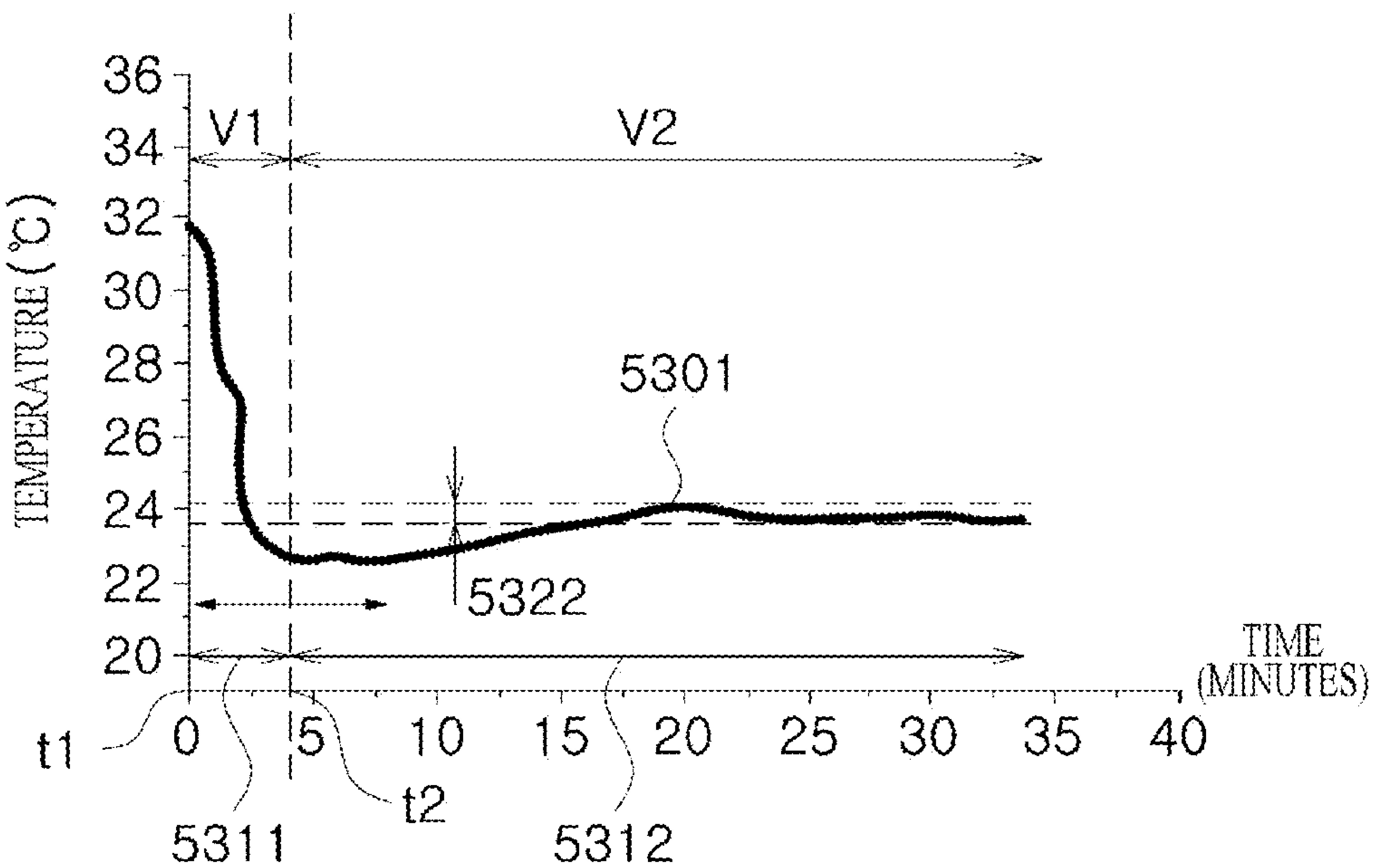

START
APPLY FIRST VOLTAGE VALUE AT FIRST TIME POINT
5410
APPLY SECOND VOLTAGE VALUE AT SECOND TIME POINT
5420
END

FIG. 55



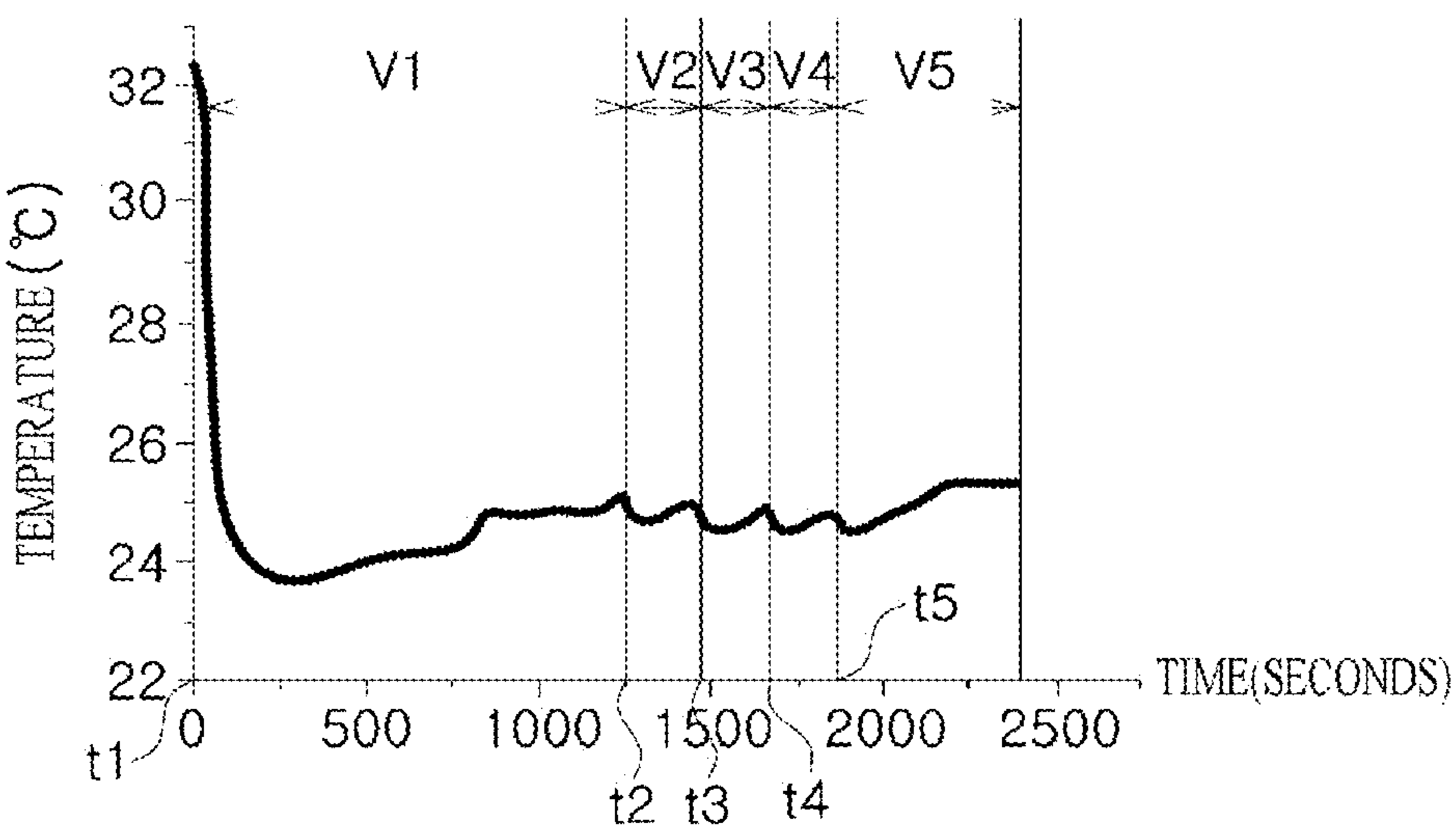
36
34
32
30
28
26
24
22
20
TEMPERATURE (℃)
V1
V2
5301
5322
TIME (MINUTES)
t1
0
5
10
15
20
25
30
35
40
t2
5311
5312

FIG. 56



36
34
32
30
28
26
24
22
20
V1
V2
TEMPERATURE (℃)
5301
5322
TIME (MINUTES)
t1
0
5
10
15
20
25
30
35
40
t2
5311
5312

FIG. 57



V1
V2
V3
V4
V5
TEMPERATURE (°C)
32
30
28
26
24
22
t5
TIME(SECONDS)
t1
0
500
1000
1500
2000
2500
t2
t3
t4

FIG. 58

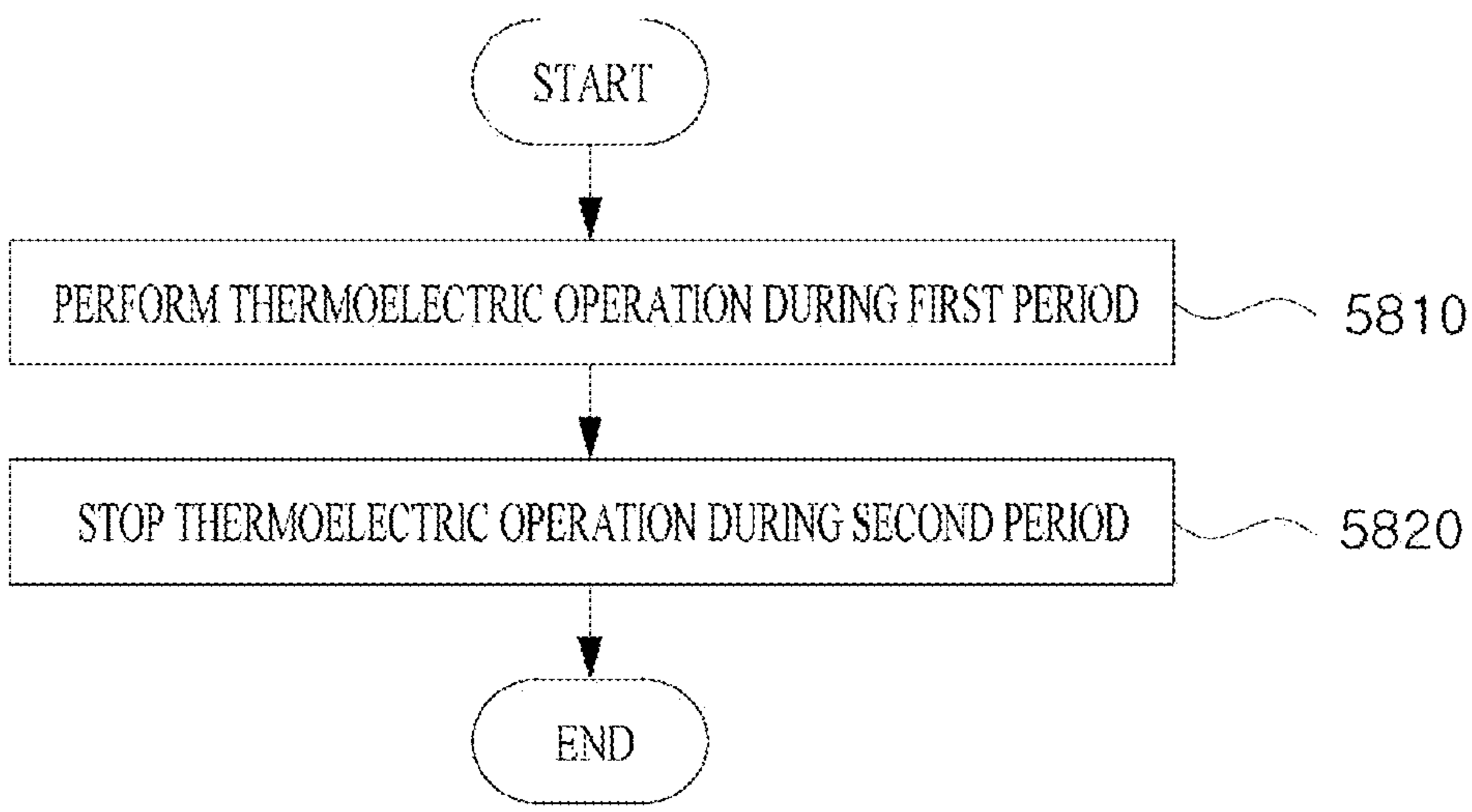

START
PERFORM THERMOELECTRIC OPERATION DURING FIRST PERIOD
5810
STOP THERMOELECTRIC OPERATION DURING SECOND PERIOD
5820
END

FIG.59

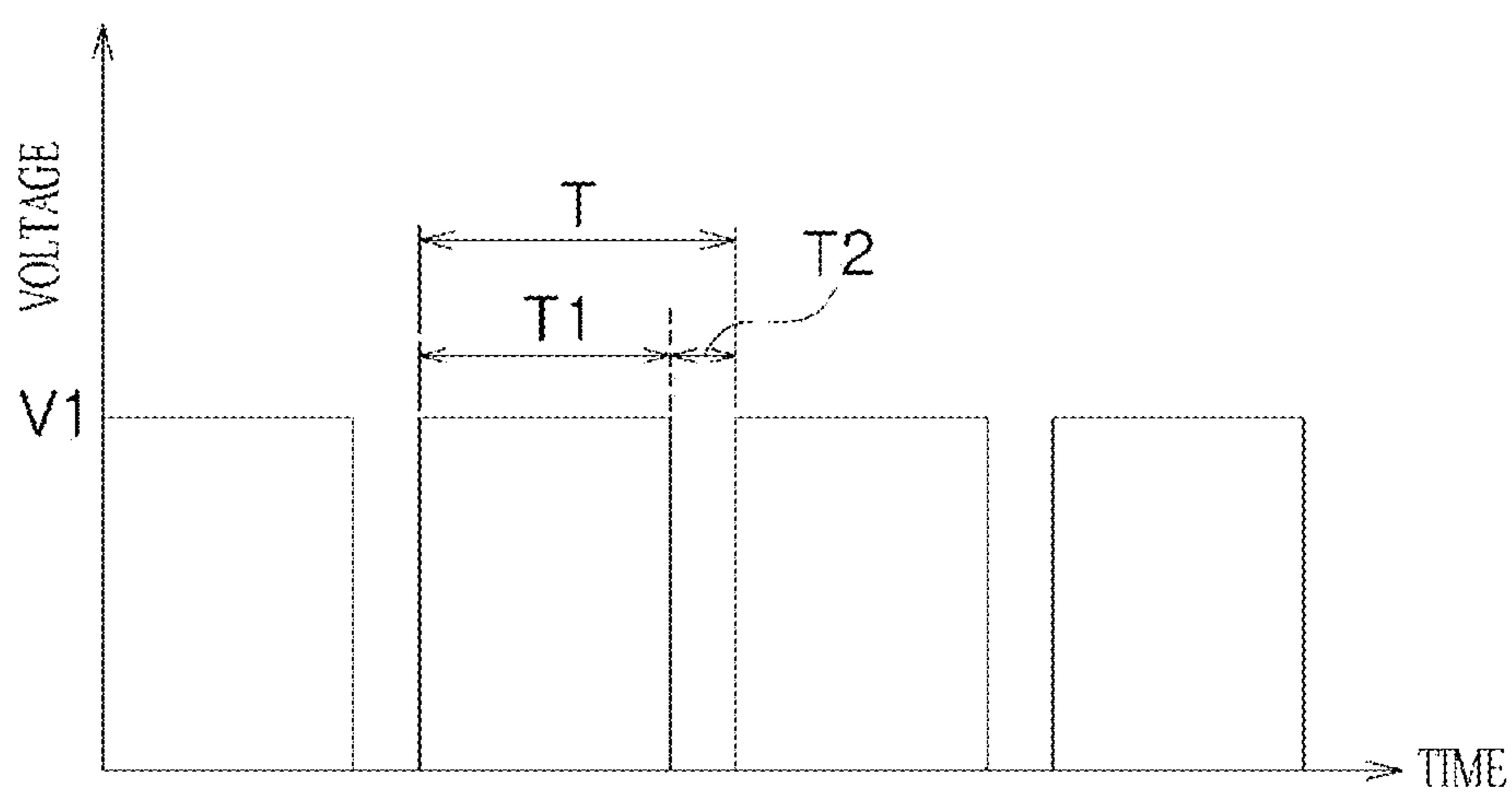
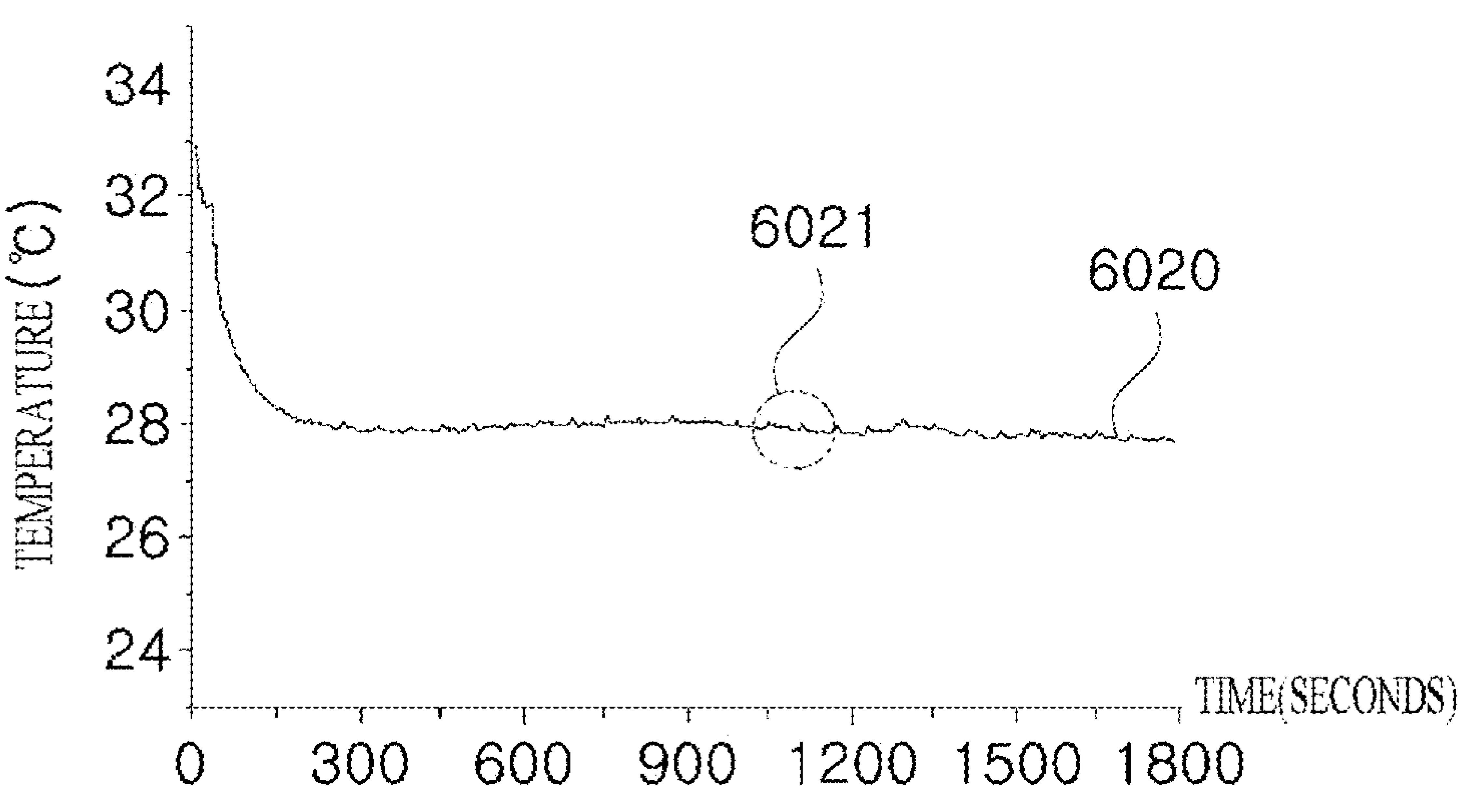


FIG. 60



34
32
30
28
26
24
TEMPERATURE (℃)
6021
6020
0
300
600
900
1200
1500
1800
TIME(SECONDS)

FIG. 61

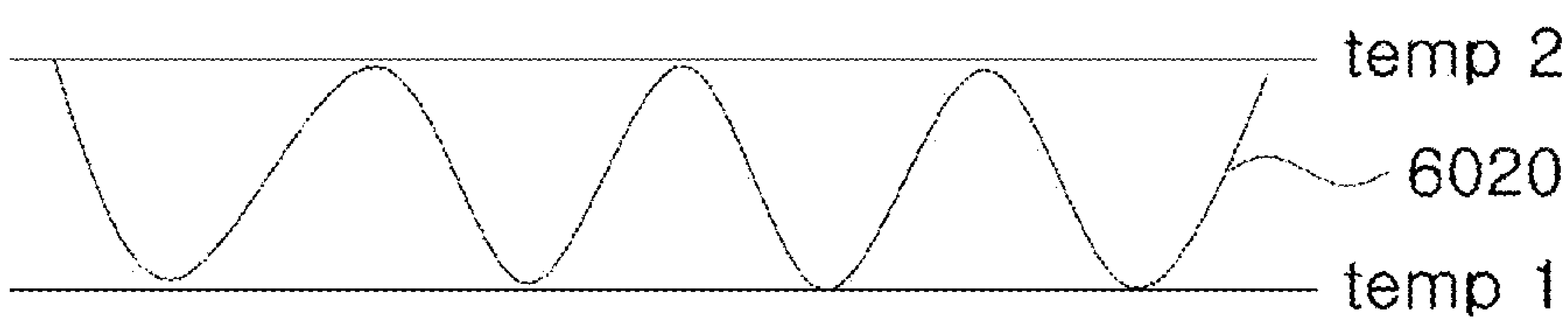


FIG. 62

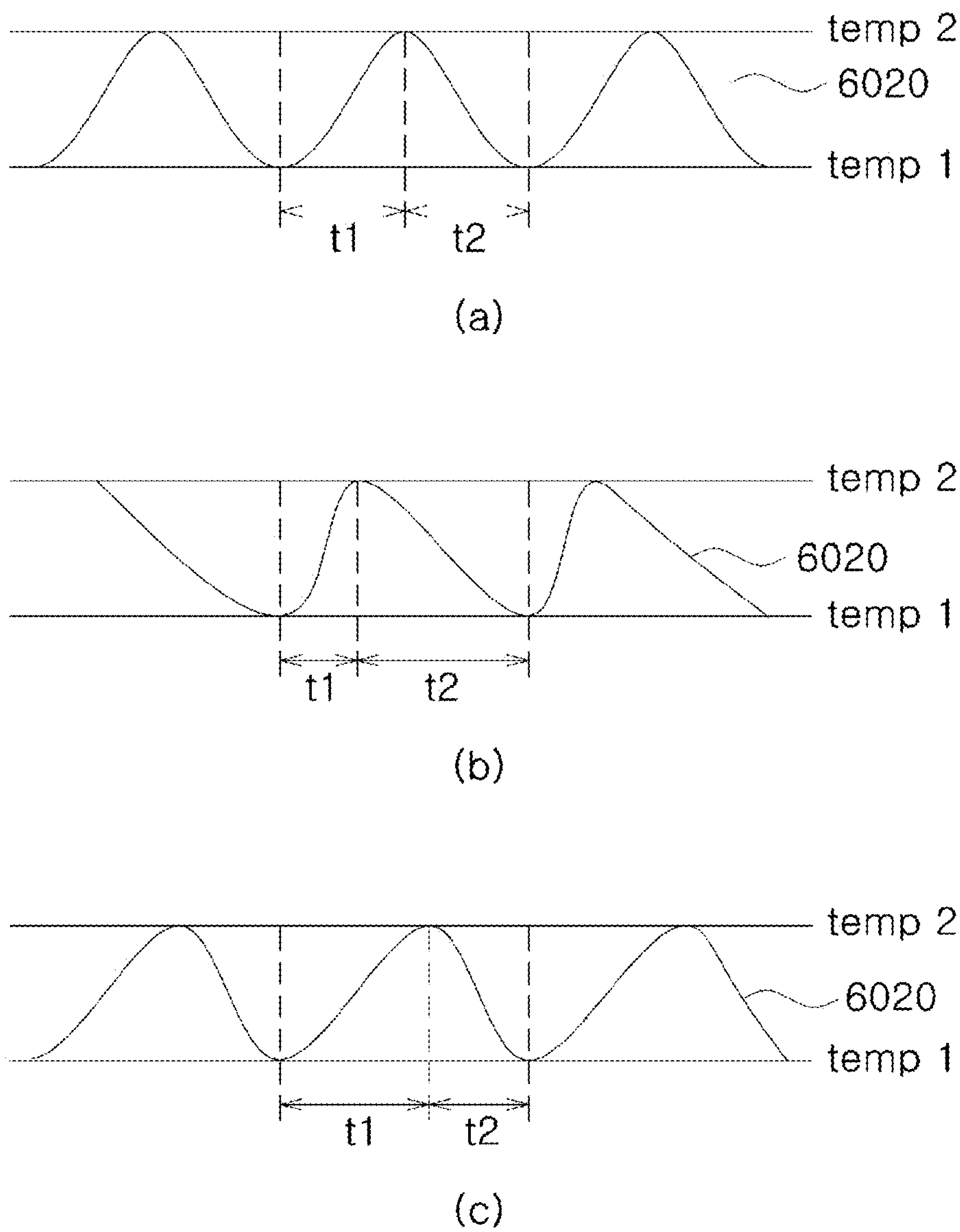

temp 2
6020
temp 1
t1
t2
(a)
temp 2
6020
temp 1
t1
t2
(b)
temp 2
6020
temp 1
t1
t2
(c)

FIG. 63

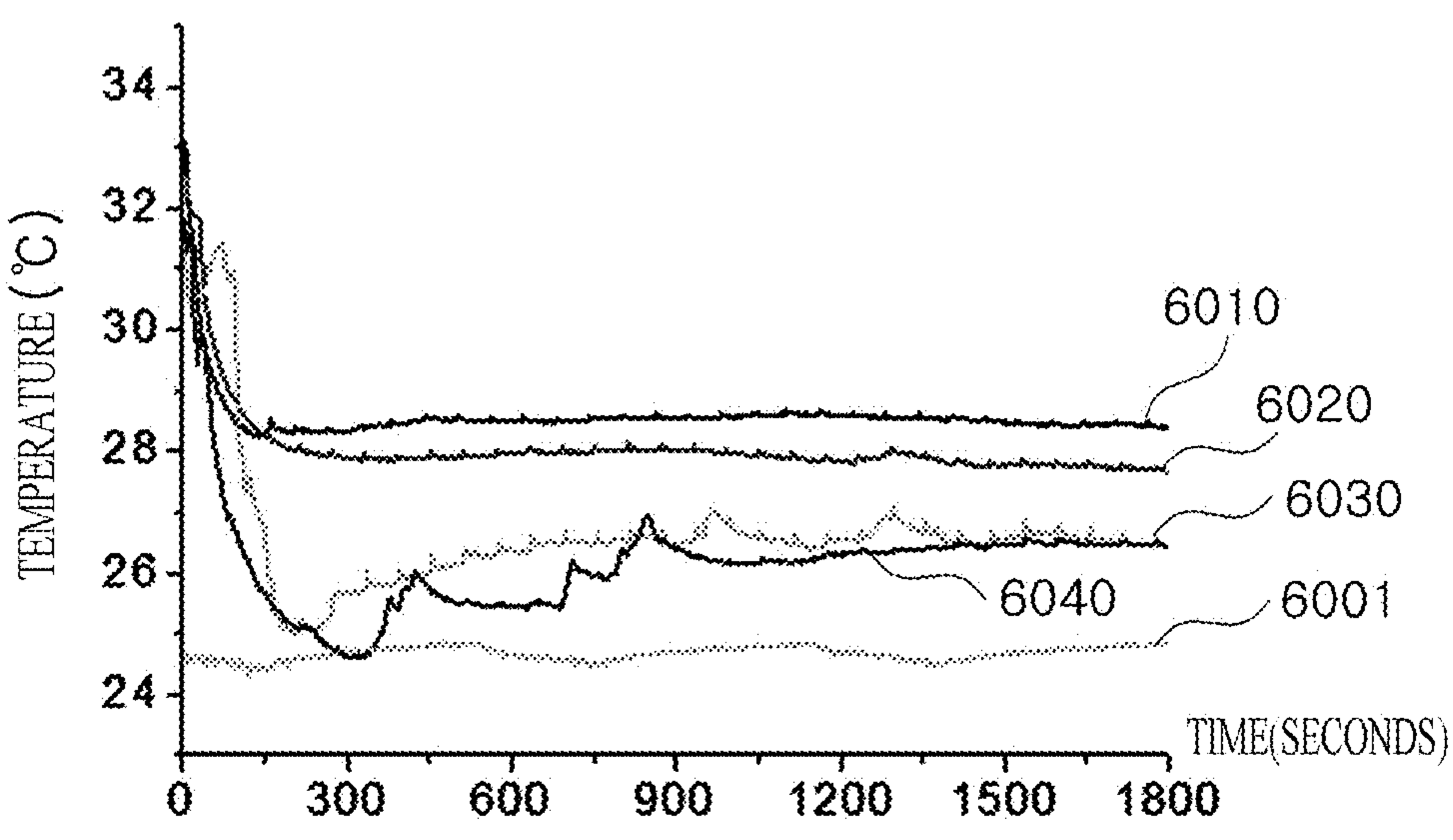
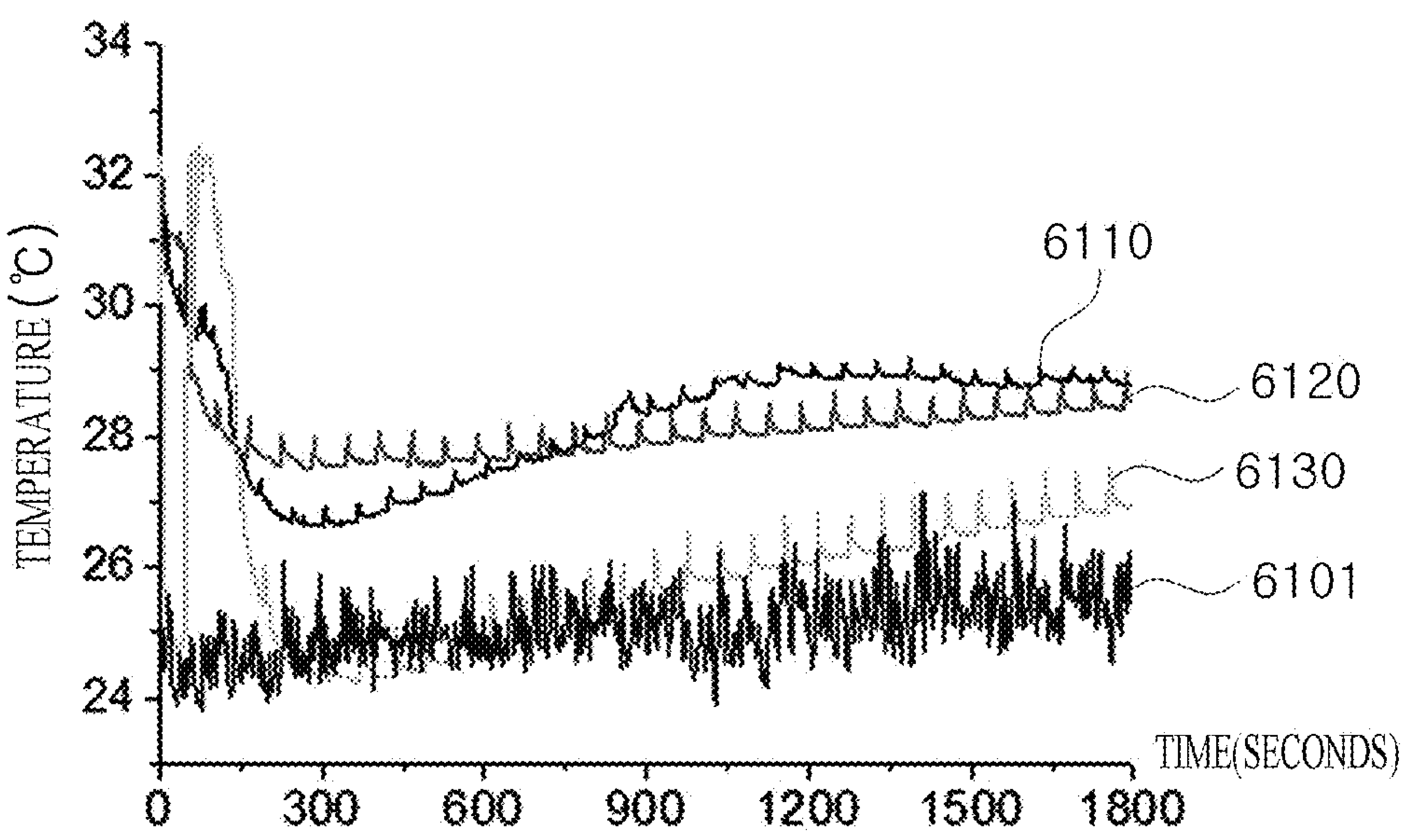
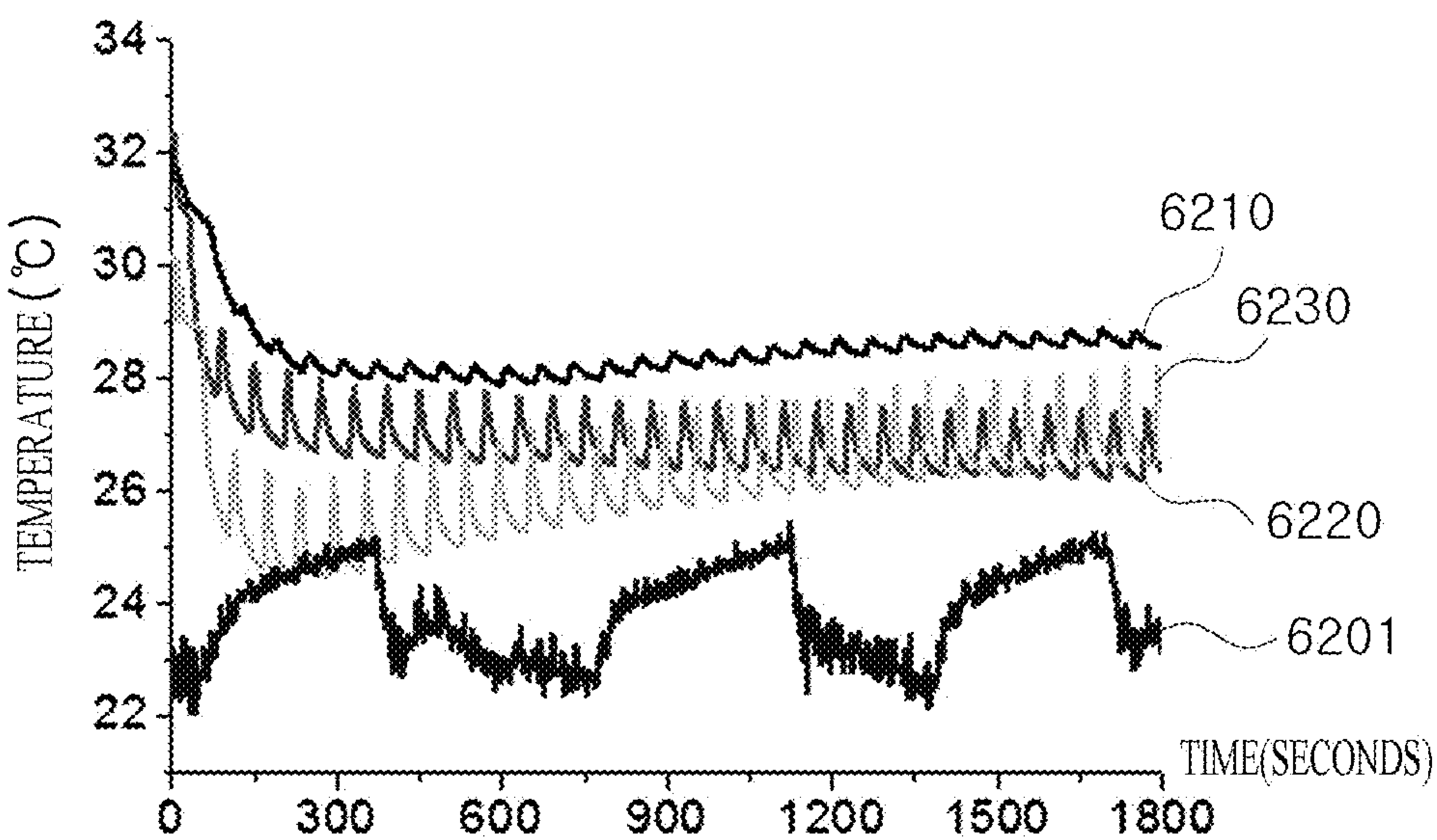

34
32
30
28
26
24
TEMPERATURE (°C)
6010
6020
6030
6040
6001
0
300
600
900
1200
1500
1800
TIME(SECONDS)

FIG. 64



34
32
30
28
26
24
TEMPERATURE (℃)
0
300
600
900
1200
1500
1800
TIME(SECONDS)
6110
6120
6130
6101

FIG. 65



34
32
30
28
26
24
22
TEMPERATURE (℃)
0
300
600
900
1200
1500
1800
TIME(SECONDS)
6210
6230
6220
6201

FEEDBACK DEVICE AND METHOD OF PROVIDING THERMAL FEEDBACK USING THE SAME

CROSS-REFERENCE TO RELATED APPLICATION

This application claims priority to and the benefit of Korean Patent Application Nos. 10-2017-0111462, 10-2017-0111463, 10-2017-0111464, 10-2017-0111465, 10-2017-0111466 and 10-2017-0111467, filed on Aug. 31, 2017, the disclosure of which is incorporated herein by reference in its entirety.

TECHNICAL FIELD

The present disclosure relates to a feedback device for outputting thermal feedback and a method of providing thermal feedback using the same.

BACKGROUND

Recently, due to development of technologies related to virtual reality (VR) or augmented reality (AR), there has been an increase in demand for providing feedback through various sensations to increase user engagement with content. VR technology in particular was mentioned as one of the most promising future technologies at the 2016 Consumer Electronics Show (CES). Following such a trend, research for providing, beyond current user experience mostly limited to the visual and auditory senses, user experience through all senses of the human body including the olfactory and tactile senses has been actively conducted.

A thermoelement (TE), which is an element that receives electrical energy and causes an exothermic reaction or an endothermic reaction due to the Peltier effect, has been expected to be used in providing thermal feedback to a user. However, a conventional TE, which mainly uses a planar substrate, is difficult to attach to a body part of a user, and thus applications of the conventional TE have been limited.

However, as development of a flexible TE (FTE) is close to success, it is expected that the problems of the conventional TE will be overcome and thermal feedback will be effectively provided to a user.

SUMMARY

It is an aspect of the present disclosure to provide a feedback device for providing thermal feedback to a user and a method of providing thermal feedback using the same.

It is another aspect of the present disclosure to provide a feedback device for effectively dissipating waste heat generated in the feedback device.

It is still another aspect of the present disclosure to provide a feedback device with improved cold sensation providing performance.

It is yet another aspect of the present disclosure to provide a method of providing thermal feedback for improving a user's degree of thermal feedback perception.

Aspects of the present disclosure are not limited to the above-mentioned aspects, and other unmentioned aspects should be clearly understood by one of ordinary skill in the art to which the present disclosure pertains from the present specification and the accompanying drawings.

In accordance with one aspect of the present disclosure, a feedback device includes a thermoelectric module including a substrate having flexibility, a thermoelement disposed on the substrate and configured to perform a thermoelectric operation for thermal feedback (the thermoelectric operation including an exothermic operation and an endothermic operation), and a contact surface disposed on the substrate, and configured to transfer heat generated through the thermoelectric operation to a user through the substrate and the contact surface to output the thermal feedback, and a feedback controller configured to control the thermoelectric module, wherein the feedback controller controls the thermoelectric module so that, after a temperature of the contact surface reaches a maximum temperature, the temperature of the contact surface is maintained within a predetermined temperature range during an entire thermoelectric operation time interval and controls the thermoelectric module so that, after the temperature of the contact surface reaches the predetermined temperature range a temperature rise or a temperature drop of exceeding a predetermined threshold value periodically occurs in the contact surface. The technical solutions of the present disclosure are not limited to the above-described methods, and other unmentioned methods should be clearly understood by one of ordinary skill in the art to which the present disclosure pertains from the present specification and the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other objects, features and advantages of the present invention will become more apparent to those of ordinary skill in the art by describing exemplary embodiments thereof in detail with reference to the accompanying drawings, in which:

FIG. **1** is a schematic of a first embodiment of a feedback device according to an embodiment of the present disclosure;

FIG. **2** is a schematic of a second embodiment of a feedback device according to an embodiment of the present disclosure;

FIG. **3** is a schematic of a third embodiment of a feedback device according to an embodiment of the present disclosure;

FIG. **4** is a schematic of a fourth embodiment of a feedback device according to an embodiment of the present disclosure;

FIG. **5** is a schematic of a fifth embodiment of a feedback device according to an embodiment of the present disclosure;

FIG. **6** is a schematic of a sixth embodiment of a feedback device according to an embodiment of the present disclosure;

FIG. **7** is a schematic of a seventh embodiment of a feedback device according to an embodiment of the present disclosure;

FIG. **8** is a schematic of an eight embodiment of a feedback device according to an embodiment of the present disclosure;

FIG. **9** is a schematic of a ninth embodiment of a feedback device according to an embodiment of the present disclosure;

FIG. **10** is a schematic of a tenth embodiment of a feedback device according to an embodiment of the present disclosure;

FIG. **11** is a schematic of an eleventh embodiment of a feedback device according to an embodiment of the present disclosure;

FIG. **12** is a schematic of a twelfth embodiment of a feedback device according to an embodiment of the present disclosure;

FIG. **13** is a block diagram of a configuration of a feedback device according to an embodiment of the present disclosure;

FIG. **14** is a block diagram of a configuration of a thermoelectric module according to an embodiment of the present disclosure;

FIG. **15** is a view illustrating one form of a thermoelectric module according to an embodiment of the present disclosure;

FIG. **16** is a view illustrating another form of the thermoelectric module according to an embodiment of the present disclosure;

FIG. **17** is a view illustrating still another form of the thermoelectric module according to an embodiment of the present disclosure;

FIG. **18** is a view illustrating yet another form of the thermoelectric module according to an embodiment of the present disclosure;

FIG. **19** is a view illustrating an exothermic operation for providing hot feedback according to an embodiment of the present disclosure;

FIG. **20** is a graph related to an intensity of hot feedback according to an embodiment of the present disclosure;

FIG. **21** is a view illustrating an exothermic operation for providing cold feedback according to an embodiment of the present disclosure;

FIG. **22** is a graph related to an intensity of cold feedback according to an embodiment of the present disclosure;

FIG. **23** is a graph related to intensities of hot/cold feedback using voltage adjustment according to an embodiment of the present disclosure;

FIG. **24** is a graph related to hot/cold feedback having the same temperature variation according to an embodiment of the present disclosure;

FIG. **25** is a view illustrating a thermal grill operation using a voltage adjustment method according to an embodiment of the present disclosure;

FIG. **26** is a table related to voltages for providing neutral thermal grill feedback in the voltage adjustment method according to an embodiment of the present disclosure;

FIG. **27** is a view for describing a liquid provider according to an embodiment of the present disclosure;

FIG. **28** is a view for describing a heat radiator according to an embodiment of the present disclosure;

FIG. **29** is a view illustrating a structure of the feedback device according to an embodiment of the present disclosure;

FIG. **30** is a view illustrating a structure of the feedback device according to another embodiment of the present disclosure;

FIG. **31** is a view illustrating a structure of the feedback device according to still another embodiment of the present disclosure;

FIG. **32** is a view illustrating a structure of the feedback device according to yet another embodiment of the present disclosure;

FIG. **33** is a view illustrating a structure of the feedback device according to yet another embodiment of the present disclosure;

FIG. **34** is a view illustrating a structure of the feedback device according to yet another embodiment of the present disclosure;

FIG. **35** is a view for describing waste heat dissipation performance according to liquid content in a liquid provider according to an embodiment of the present disclosure;

FIG. **36** is a view for describing liquid absorption performance and liquid holding performance according to a cross-link density of the liquid provider according to an embodiment of the present disclosure;

FIG. **37** is as view for describing waste heat dissipation performance according to the liquid absorption performance and the liquid holding performance according to an embodiment of the present disclosure;

FIG. **38** is a view for describing liquid absorption performance and liquid holding performance according to a cross-link density of the liquid provider according to another embodiment of the present disclosure;

FIG. **39** is a view for describing liquid absorption performance and liquid holding performance according to a cross-link density of the liquid provider according to still another embodiment of the present disclosure;

FIG. **40** is a view for describing liquid transfer according to liquid permeability of the liquid provider according to an embodiment of the present disclosure;

FIG. **41** is a view for describing waste heat dissipation performance according to a function of a heat transferer according to an embodiment of the present disclosure;

FIG. **42** is a view describing waste heat dissipation performance according to a function of a heat dissipator according to a first embodiment of the present disclosure;

FIG. **43** is a view describing waste heat dissipation performance according to a function of a heat dissipator according to a second embodiment of the present disclosure;

FIG. **44** is a block diagram of a configuration of the feedback device according to another embodiment of the present disclosure;

FIG. **45** is a view for describing a property of a thermal buffer material according to an embodiment of the present disclosure;

FIG. **46** is a view illustrating a structure of the feedback device to which the thermal buffer material is applied according to an embodiment of the present disclosure;

FIG. **47** is a view illustrating a structure of the feedback device to which the thermal buffer material is applied according to another embodiment of the present disclosure;

FIG. **48** is a view illustrating a structure of the feedback device to which the thermal buffer material is applied according to still another embodiment of the present disclosure;

FIG. **49** is a view illustrating a structure of the feedback device to which the thermal buffer material is applied according to yet another embodiment of the present disclosure;

FIG. **50** is view illustrating a structure of the feedback device to which the thermal buffer material is applied according to yet another embodiment of the present disclosure;

FIG. **51** is a view for describing cold sensation providing performance that is improved by the thermal buffer material according to an embodiment of the present disclosure;

FIG. **52** is a view for describing cold sensation providing performance that is improved by the thermal buffer material according to another embodiment of the present disclosure;

FIG. **53** is a view illustrating a graph related to a temperature of heat provided to a user from the feedback device according to an embodiment of the present disclosure;

FIG. **54** is an operational flowchart illustrating a method of improving a user's perception performance by applying a plurality of voltages according to an embodiment of the present disclosure;

FIG. **55** is a view for describing cold heat transfer performance of the feedback device by adjusting a voltage according to an embodiment of the present disclosure;

FIG. **56** is a view for describing cold heat transfer performance of the feedback device by adjusting a time point at which a voltage is applied according to an embodiment of the present disclosure;

FIG. **57** is a view for describing cold heat transfer performance of the feedback device in response to applying a plurality of voltages according to an embodiment of the present disclosure;

FIG. **58** is an operational flowchart illustrating a method of improving the user's perception performance by controlling a thermoelectric operation according to an embodiment of the present disclosure;

FIG. **59** is a view for describing periods for controlling a thermoelectric operation according to an embodiment of the present disclosure;

FIG. **60** is a view for describing a method of improving the user's perception performance by controlling a thermoelectric operation according to an embodiment of the present disclosure;

FIG. **61** is a view for describing a temperature change of a contact surface due to controlling a thermoelectric operation according to an embodiment of the present disclosure;

FIG. **62** is a view for describing a temperature change of the contact surface due to controlling a thermoelectric operation according to another embodiment of the present disclosure; and

FIG. **63** is a first view describing a temperature change of the contact surface due to controlling a thermoelectric operation according to another embodiment of the present disclosure.

FIG. **64** is a second view for describing a temperature change of the contact surface due to controlling a thermoelectric operation according to still another embodiment of the present disclosure.

FIG. **65** is a third view for describing a temperature change of the contact surface due to controlling a thermoelectric operation according to still another embodiment of the present disclosure.

DETAILED DESCRIPTION

To achieve the above-described objectives, in accordance with one aspect of the present disclosure, a feedback device includes a thermoelectric module including a substrate having flexibility, a thermoelement disposed on the substrate and configured to perform a thermoelectric operation for thermal feedback (the thermoelectric operation including an exothermic operation and an endothermic operation), and a contact surface disposed on the substrate, and configured to transfer heat generated through the thermoelectric operation to a user through the substrate and the contact surface to output the thermal feedback, and a feedback controller configured to control the thermoelectric module, wherein the feedback controller controls the thermoelectric module so that, after a temperature of the contact surface reaches a maximum temperature, the temperature of the contact surface is maintained within a predetermined temperature range during an entire thermoelectric operation time interval and controls the thermoelectric module so that, after the temperature of the contact surface reaches the predetermined temperature range, a temperature rise or a temperature drop of exceeding a predetermined threshold value periodically occurs in the contact surface.

Because embodiments described herein are for clearly describing the spirit of the present disclosure to one of ordinary skill in the art to which the present disclosure pertains, the present disclosure is not limited by the embodiments described herein, and the scope of the present disclosure should be construed as including modifications that do not depart from the spirit of the present disclosure.

Terms used herein are currently widely used general terms that are selected in consideration of functions in the present disclosure, but the terms may vary depending on an intention, practice of one of ordinary skill in the art to which the present disclosure pertains or the advent of new technology. However, unlike this, when a specific term is arbitrarily defined and used, a definition of the term will be separately given. Consequently, the terms used herein should be interpreted on the basis of substantial meanings thereof and entire content herein instead of being interpreted simply on the basis of the names of the terms.

The accompanying drawings are for facilitating description of the present disclosure. Because shapes illustrated in the drawings may be exaggerated as necessary to assist in understanding the present disclosure, the present disclosure is not limited by the drawings.

When detailed descriptions of known configurations or functions related to the present disclosure are deemed as having the possibility of blurring the gist of the present disclosure, the detailed descriptions thereof will be omitted as necessary.

In accordance with one aspect of the present disclosure, a feedback device includes a thermoelectric module including a substrate having flexibility, a thermoelement disposed on the substrate and configured to perform a thermoelectric operation for thermal feedback (the thermoelectric operation including an exothermic operation and an endothermic operation), and a contact surface disposed on the substrate, and configured to transfer heat generated through the thermoelectric operation to a user through the substrate and the contact surface to output the thermal feedback, and a feedback controller configured to control the thermoelectric module, wherein the feedback controller controls the thermoelectric module so that, after a temperature of the contact surface reaches a maximum temperature, the temperature of the contact surface is maintained within a predetermined temperature range during an entire thermoelectric operation time interval and controls the thermoelectric module so that, after the temperature of the contact surface reaches the predetermined temperature range, a temperature rise or a temperature drop of exceeding a predetermined threshold value periodically occurs in the contact surface.

Here, the feedback controller may apply a first voltage, which causes the thermoelectric module to perform the endothermic operation, to the thermoelectric module so that the feedback device provides cold sensation to the user.

Here, the feedback device may apply the first voltage, which is in the form of a duty signal.

Here, the feedback controller may control the thermoelectric module so that, after the temperature of the contact surface reaches a minimum temperature from an initial temperature, the temperature of the contact surface is maintained within a predetermined saturation temperature range during an entire thermoelectric operation time interval.

Here, the predetermined saturation temperature range may be from a temperature higher than the minimum temperature to a temperature lower than the initial temperature.

Here, waste heat may be accumulated inside the feedback device as the thermoelectric module performs the endothermic operation, and the temperature of the contact surface may rise from the minimum temperature to a temperature within the predetermined saturation temperature range due to the waste heat.

Here, the feedback device may further include a heat radiator configured to dissipate at least a portion of the waste heat to the outside of the feedback device, and as at least a portion of the waste heat is dissipated to the outside of the feedback device by the heat radiator, the temperature of the contact surface may be maintained within the saturation temperature range.

Here, the feedback controller may control the thermoelectric module for a first time during which the endothermic operation is performed and a second time during which the endothermic operation is not performed to be periodically repeated so that, after the temperature of the contact surface reaches the saturation temperature range, a temperature rise or a temperature drop of exceeding a predetermined threshold value periodically occurs in the contact surface.

Here, the feedback controller may apply the first voltage to the thermoelectric module during the first time and not apply the first voltage to the thermoelectric module during the second time so that the first time and the second time are periodically repeated.

Here, the feedback controller may control the thermoelectric module so that a temperature variation of the contact surface during the first time and the second time is larger than or equal to a threshold temperature difference indicating a temperature difference that allows the user to perceive a temperature change.

Here, the threshold temperature difference may be changed according to the saturation temperature range.

Here, the temperature variation of the contact surface may be adjusted according to a proportion between the first time and the second time.

Here, the feedback controller may check the saturation temperature range, set the threshold temperature difference on the basis of the saturation temperature range, and set the proportion between the first time and the second time so that the temperature variation of the contact surface becomes larger than or equal to the threshold temperature difference.

Here, a temperature variation of the contact surface when the proportion between the first time and the second time is a first proportion may be a first temperature variation, a temperature variation of the contact surface when the proportion between the first time and the second time is a second proportion may be a second temperature variation, the first temperature variation and the second temperature variation may be larger than or equal to the threshold temperature difference, and when the first temperature variation is higher than the second temperature variation, the feedback controller may control the thermoelectric module so that the temperature variation of the contact surface becomes the first temperature variation.

Here, the feedback controller may set a sum of the first time and the second time to be less than 60 seconds.

Here, the feedback controller may control the thermoelectric module so that a proportion of the second time to the first time is higher than or equal to 0.9.

In accordance with another aspect of the present disclosure, a method of improving cold feeling of a user being performed by a feedback device, which includes a thermoelectric module including a substrate having flexibility, a thermoelement disposed on the substrate and configured to perform an endothermic operation for cold feedback, and a contact surface disposed on the substrate, and configured to transfer cold heat generated through the thermoelectric operation to a user through the substrate and the contact surface to output the cold feedback, and a feedback controller configured to control the thermoelectric module, includes controlling the thermoelectric module so that, after a temperature of the contact surface reaches a maximum temperature, the temperature of the contact surface is maintained within a predetermined temperature range during an entire thermoelectric operation time interval, and controlling the thermoelectric module so that, after the temperature of the contact surface reaches the predetermined temperature range a temperature rise or a temperature drop of exceeding a predetermined threshold value periodically occurs in the contact surface.

In accordance with still another aspect of the present disclosure, a feedback device includes a thermoelectric module including a substrate having flexibility, a thermoelement disposed on the substrate and configured to perform a thermoelectric operation for thermal feedback (the thermoelectric operation including an exothermic operation and an endothermic operation), and a contact surface disposed on the substrate, and configured to transfer heat generated through the thermoelectric operation to a user through the substrate and the contact surface to output the thermal feedback, and a feedback controller configured to control the thermoelectric module, wherein the feedback controller applies a first voltage, which causes the thermoelectric module to perform the thermoelectric operation, to the thermoelectric module during a first voltage application time and applies a second voltage, which causes the thermoelectric module to perform the thermoelectric operation, to the thermoelectric module during a second voltage application time so that the user's degree of perception on warmth provided to the user by the thermoelectric operation is improved.

Here, the feedback controller applies the first voltage and the second voltage, which cause the thermoelectric module to perform the endothermic operation, to the thermoelectric module so that the feedback device provides cold sensation to the user.

Here, the feedback device may apply the first voltage and the second voltage, which are in the form of a duty signal.

Here, waste heat may be generated inside the feedback device as the thermoelectric module performs the endothermic operation, and the temperature of the contact surface may rise due to the waste heat.

Here, the feedback controller may set a level of the first voltage to be higher than that of a reference voltage so that the temperature of the contact surface during the first voltage application time becomes lower in comparison to a case in which the reference voltage is applied during the first voltage application time and the second voltage application time (when the reference voltage is applied to the thermoelectric module, thermal feedback of a reference intensity is output from the feedback device).

Here, the feedback controller may set the level of the first voltage to be lower than that of the reference voltage so that the amount of waste heat generated during the first voltage application time is reduced in comparison to when the reference voltage is applied during the first voltage application time and the second voltage application time (when the reference voltage is applied to the thermoelectric module, the thermal feedback of the reference intensity is output from the feedback device).

Here, the feedback controller may set a level of the second voltage to be higher than that of the reference voltage so that the temperature of the contact surface during the second voltage application time becomes lower in comparison to when the reference voltage is applied during the first voltage application time and the second voltage application time (when the reference voltage is applied to the thermoelectric module, the thermal feedback of the reference intensity is output from the feedback device).

Here, the feedback controller may set the level of the second voltage to be lower than that of the reference voltage so that the amount of waste heat generated during the second voltage application time is reduced in comparison to when the reference voltage is applied during the first voltage application time and the second voltage application time (when the reference voltage is applied to the thermoelectric module, the thermal feedback of the reference intensity is output from the feedback device).

Here, the feedback controller may control the thermoelectric module so that, after the temperature of the contact surface reaches a minimum temperature from an initial temperature during the first voltage application time, the temperature of the contact surface is maintained within a predetermined temperature range during the second voltage application time.

Here, the feedback controller may set the level of the first voltage to be larger than that of the second voltage.

Here, the feedback controller may apply the first voltage to the thermoelectric module during the first voltage application time so that the amount of time taken for the temperature of the contact surface to reach the minimum temperature is shortened.

Here, the feedback controller may apply the second voltage to the thermoelectric module during the second voltage application time so that the amount of time during which the temperature of the contact surface is maintained within the predetermined temperature range becomes longer.

Here, the feedback controller may apply the first voltage to the thermoelectric module during the first voltage application time so that a temperature within the predetermined temperature range becomes lower and may apply the second voltage or a third voltage (the third voltage has a level higher than that of the second voltage and lower than that of the first voltage) to the thermoelectric module during the second voltage application time.

In accordance with yet another aspect of the present disclosure, a method of improving cold feeling of a user being performed by a feedback device, which includes a thermoelectric module including a substrate having flexibility, a thermoelement disposed on the substrate and configured to perform an endothermic operation for cold feedback, and a contact surface disposed on the substrate, and configured to transfer cold heat generated through the thermoelectric operation to a user through the substrate and the contact surface to output the cold feedback, and a feedback controller configured to control the thermoelectric module, includes applying a first voltage, which causes the thermoelectric module to perform the endothermic operation, to the thermoelectric module during a first voltage application time, and applying a second voltage, which causes the thermoelectric module to perform the endothermic operation, to the thermoelectric module during a second voltage application time so that the user's degree of perception on the cold sensation provided to the user by the endothermic operation is improved.

In accordance with yet another aspect of the present disclosure, a feedback device includes a thermoelectric module including a substrate having flexibility, a thermoelement disposed on the substrate and configured to perform a thermoelectric operation for thermal feedback (the thermoelectric operation including an exothermic operation and an endothermic operation), and a contact surface disposed on the substrate, and configured to transfer heat generated through the thermoelectric operation to a user through the substrate and the contact surface to output the thermal feedback, a heat radiator configured to dissipate waste heat to the outside when the waste heat is generated as the thermoelement performs the thermoelectric operation, and a liquid provider configured to supply a liquid to the heat radiator so that the waste heat is dissipated in the form of latent heat.

Here, the feedback device may apply a first voltage, which causes the thermoelectric module to perform the endothermic operation, to the thermoelectric module so that the feedback device provides cold sensation to the user.

Here, the feedback device may apply the first voltage, which is in the form of a duty signal.

Here, the heat radiator may include a heat transferer configured to transfer the waste heat and a heat dissipator configured to dissipate the waste heat to the outside in the form of latent heat.

Here, the heat radiator may be disposed on the thermoelectric module, and the liquid provider may be disposed inside the heat radiator so that a dissipation path of the waste heat consists of the thermoelectric module, the heat transferer, the liquid provider, and the heat dissipator.

Here, a thickness of the liquid provider may be adjusted so that the dissipation path of the waste heat is shortened.

Here, the heat radiator may be disposed on the thermoelectric module, and the liquid provider may be disposed at a side surface of the heat radiator and not come into contact with the thermoelectric module so that the dissipation path of the waste heat consists of the thermoelectric module and the heat radiator.

Here, the liquid provider may include a first liquid provider and a second liquid provider, the first liquid provider may be disposed at one side surface of the heat radiator, and the second liquid provider may be disposed at another side surface of the heat radiator.

Here, the feedback device may further include a protector configured to protect the feedback device from the outside, and when the dissipation path of the waste heat includes the thermoelectric module and the heat radiator, the protector may be disposed on the heat radiator to make contact between the heat radiator and the user difficult.

Here, the liquid provider may include a super absorbent polymer (SAP).

Here, when the heat transferer is formed of a first material, and the heat dissipator is formed of a second material, heat transfer performance and air permeability may differ between the first material and the second material.

Here, materials of the heat transferer and the heat dissipator may be the same.

Here, at least one of the liquid provider and the heat radiator may be configured to be separated from the feedback device.

In accordance with yet another aspect of the present disclosure, a cooling device includes a thermoelectric module including a substrate having flexibility, a thermoelement disposed on the substrate and configured to perform an endothermic operation for cold feedback, and a contact surface disposed on the substrate, and configured to transfer cold heat generated through the endothermic operation to a user through the substrate and the contact surface to output the cold feedback, a heat radiator configured to dissipate waste heat to the outside when the waste heat is generated as the thermoelement performs the endothermic operation, a liquid provider configured to supply a liquid to the heat radiator so that the waste heat is dissipated in the form of latent heat, and a supporter disposed to come into contact with the user and configured to support the thermoelectric module, the heat radiator, and the liquid provider.

In accordance with yet another aspect of the present disclosure, a feedback device includes a thermoelectric module including a thermoelement configured to perform a thermoelectric operation for thermal feedback (the thermoelectric operation including an exothermic operation and an endothermic operation), and a contact surface thermally connected to the TE, and configured to transfer heat generated through the thermoelectric operation to a user through the contact surface to output the thermal feedback, a heat radiator configured to dissipate waste heat to the outside when the waste heat is generated as the thermoelement performs the thermoelectric operation, and a liquid provider configured to supply a liquid to the heat radiator so that the waste heat is dissipated in the form of latent heat.

In accordance with yet another aspect of the present disclosure, a feedback device includes a thermoelectric module including a substrate having flexibility, a thermoelement disposed on the substrate and configured to perform a thermoelectric operation for thermal feedback (the thermoelectric operation including an exothermic operation and an endothermic operation), and a contact surface disposed on the substrate, and configured to transfer heat generated through the thermoelectric operation to a user through the substrate and the contact surface to output the thermal feedback, a heat radiator configured to dissipate waste heat to the outside when the waste heat is generated as the thermoelement performs the thermoelectric operation, and a first liquid provider connected to one region of the heat radiator and configured to supply a liquid to the heat radiator so that the waste heat is dissipated in the form of latent heat, wherein the amount of the liquid supplied to the heat radiator is adjusted according to performance of the first liquid provider.

Here, the performance of the first liquid provider may include liquid absorption performance indicating an extent to which a liquid is absorbed from the outside and liquid holding performance indicating an extent to which a liquid is held instead of being dissipated to the outside when a predetermined pressure is applied from the outside.

Here, the first liquid provider may include an SAP.

Here, the liquid absorption performance and the liquid holding performance of the first liquid provider may be adjusted by a crosslink density of the SAP.

Here, when the first liquid provider is formed of a first SAP having a crosslink of a first density, a larger amount of liquid may be provided to the heat radiator in comparison to a case in which the first liquid provider is formed of a second SAP having a crosslink of a second density (the second density is higher than the first density).

Here, the first liquid provider may include a first region at a lower portion and a second region at an upper portion, the first region may include the first SAP, the second region may include the second SAP, and crosslink densities of the first SAP and the second SAP may be different from each other.

Here, the first liquid provider may include a first region and a second region configured to cover the first region, the first region may include the first SAP, the second region may include the second SAP, and crosslink densities of the first SAP and the second SAP may be different from each other.

Here, the feedback device may further include a second liquid provider having higher liquid absorption performance than that of the first liquid provider, and the second liquid provider may provide a liquid to the first liquid provider so that the first liquid provider is supplemented with the liquid.

Here, at least one of the first liquid provider, the second liquid provider, and the heat radiator may be configured to be separated from the feedback device.

Here, the feedback device may apply a first voltage, which causes the thermoelectric module to perform the endothermic operation, to the thermoelectric module so that the feedback device provides cold sensation to the user.

Here, the feedback device may apply the first voltage, which is in the form of a duty signal.

In accordance with yet another aspect of the present disclosure, a cooling device includes a thermoelectric module including a substrate having flexibility, a thermoelement disposed on the substrate and configured to perform an endothermic operation for cold feedback, and a contact surface disposed on the substrate, and configured to transfer cold heat generated through the thermoelectric operation to a user through the substrate and the contact surface to output the cold feedback, a heat radiator configured to dissipate waste heat to the outside when the waste heat is generated as the thermoelement performs the endothermic operation, and a first liquid provider connected to one region of the heat radiator and configured to supply a liquid to the heat radiator so that the waste heat is dissipated in the form of latent heat, wherein the amount of the liquid supplied to the heat radiator is adjusted according to performance of the first liquid provider.

In accordance with yet another aspect of the present disclosure, a feedback device includes a thermoelectric module including a substrate having flexibility, a thermoelement disposed on the substrate and configured to perform a thermoelectric operation for thermal feedback (the thermoelectric operation including an exothermic operation and an endothermic operation), and a contact surface disposed on the substrate, and configured to transfer heat generated through the thermoelectric operation to a user through the substrate and the contact surface to output the thermal feedback, a heat radiator configured to dissipate waste heat to the outside when the waste heat is generated as the thermoelement performs the thermoelectric operation, a liquid provider configured to provide moisture to the heat radiator so that the waste heat is dissipated in the form of latent heat, and a thermal buffer material formed of a material that absorbs a predetermined amount of heat from the outside and configured to delay a temperature rise of the contact surface due to the waste heat.

Here, the feedback device may apply a first voltage, which causes the thermoelectric module to perform the endothermic operation, to the thermoelectric module so that the feedback device provides cold sensation to the user.

Here, the feedback device may apply the first voltage, which is in the form of a duty signal.

Here, the thermal buffer material may be formed as an independent material and disposed in the heat radiator for the heat radiator to absorb the waste heat.

Here, the thermal buffer material may be disposed in the form of a layer.

Here, the heat radiator may be disposed on the thermoelectric module, the liquid provider may be disposed inside the heat radiator, and the thermal buffer material may be disposed in the form of a layer between the heat radiator and the thermoelectric module so that a time at which the waste heat is transferred to the heat radiator is delayed.

Here, the heat radiator may include a heat transferer configured to transfer the waste heat and a heat dissipator configured to dissipate the waste heat in the form of latent heat, the heat radiator may be disposed on the thermoelectric module, the liquid provider may be disposed inside the heat radiator and between the heat transferer and the heat dissipator, and the thermal buffer material may be disposed in the form of a layer between the heat transferer and the liquid provider so that a time at which the waste heat is transferred to the liquid provider is delayed.

Here, the heat radiator may be disposed on the thermoelectric module, and the liquid provider may be disposed at a side surface of the heat radiator and not come into contact with the thermoelectric module so that a dissipation path of the waste heat consists of the thermoelectric module and the heat radiator, and the thermal buffer material may be disposed in the form of a layer between the heat radiator and the thermoelectric module so that a time at which the waste heat is transferred to the heat radiator is delayed.

Here, the thermal buffer material may include a phase change material (PCM).

Here, a temperature of the thermal buffer material may be maintained without rising while a predetermined amount of heat is being absorbed.

Here, a phase of the thermal buffer material may be changed from a solid to a liquid while the predetermined amount of heat is being absorbed.

Here, the thermal buffer material may include xylitol or erythritol and be implemented as an independent material.

Here, the thermal buffer material may be included in a predetermined capsule and be implemented as an independent material.

Here, the thermal buffer material may be configured to be separated from the feedback device so that, when the thermal buffer material absorbs the waste heat, the waste heat is dissipated to the outside from outside the feedback device.

In accordance with yet another aspect of the present disclosure, a cooling device includes a thermoelectric module including a substrate having flexibility, a thermoelement disposed on the substrate and configured to perform an endothermic operation for cold feedback, and a contact surface disposed on the substrate, and configured to transfer cold heat generated through the endothermic operation to a user through the substrate and the contact surface to output the cold feedback, a heat radiator configured to dissipate waste heat to the outside when the waste heat is generated as the thermoelement performs the thermoelectric operation, a liquid provider configured to supply moisture to the heat radiator so that the waste heat is dissipated in the form of latent heat, a thermal buffer material formed of a material that absorbs a predetermined amount of heat from the outside and configured to delay a temperature rise of the contact surface due to the waste heat, and a supporter disposed to come into contact with the user and configured to support the thermoelectric module, the heat radiator, the liquid provider, and the thermal buffer material.

In accordance with yet another aspect of the present disclosure, a feedback device includes a thermoelectric module including a thermoelement configured to perform a thermoelectric operation for thermal feedback (the thermoelectric operation including an exothermic operation and an endothermic operation), and a contact surface thermally connected to the TE, and configured to transfer heat generated through the thermoelectric operation to a user through the contact surface to output the thermal feedback, a heat radiator configured to dissipate waste heat to the outside when the waste heat is generated as the thermoelement performs the thermoelectric operation, a liquid provider configured to provide moisture to the heat radiator so that the waste heat is dissipated in the form of latent heat, and a thermal buffer material formed of a material that absorbs a predetermined amount of heat from the outside and configured to delay the temperature rise of the contact surface due to the waste heat.

In accordance with yet another aspect of the present disclosure, a method of controlling a temperature inside a feedback device that performs a thermoelectric operation (the thermoelectric operation including an exothermic operation and an endothermic operation) and provides thermal feedback to the user includes, when waste heat is generated inside the feedback device as the thermoelectric operation is performed, dissipating the waste heat to the outside of the feedback device, when the amount of the generated waste heat is larger than that of the dissipated waste heat, increasing the temperature inside the feedback device up to a first temperature range, and maintaining the temperature inside the feedback device within the first temperature range during a predetermined amount of time so that a temperature rise inside the feedback device is delayed.

Here, the dissipating of the waste heat to the outside of the feedback device may include dissipating the waste heat in the form of latent heat by using a liquid included in the feedback device.

Here, the dissipating of the waste heat to the outside of the feedback device may include acquiring the liquid from a liquid provider included in the feedback device.

Here, the maintaining of the temperature inside the feedback device within the first temperature range may include delaying a temperature rise of a contact surface, at which a user comes into contact with the feedback device, due to the waste heat.

Here, the maintaining of the temperature inside the feedback device within the first temperature range may include adjusting the temperature inside the feedback device to be within the first temperature range by using a thermal buffer material.

Here, the thermal buffer material may include a PCM.

Here, the maintaining of the temperature inside the feedback device within the first temperature range may include absorbing the waste heat by the thermal buffer material and controlling a temperature of a surface of the thermal buffer material to be maintained within a second temperature range during a predetermined amount of time.

Here, a phase change may occur inside the thermal buffer material while the temperature of the surface of the thermal buffer material is maintained within the second temperature range.

Here, the thermal buffer material may be changed from a solid to a liquid while the temperature of the surface of the thermal buffer material is maintained within the second temperature range.

Here, a highest temperature within the second temperature range may be lower than a highest temperature within the first temperature range.

Here, the thermal buffer material may be formed in a separate shape with a separate material or be formed in the form of a layer and included in the feedback device.

Here, the method of controlling the temperature inside the feedback device may further include performing the endothermic operation so that cold feedback of the thermal feedback is provided to a user.

In accordance with yet another aspect of the present disclosure, a method of controlling a temperature of a cooling device that performs an endothermic operation and provides cold feedback to a user includes, when waste heat is generated inside the cooling device as the endothermic operation is performed, dissipating the waste heat to outside of the cooling device, when the amount of the generated waste heat is larger than that of the dissipated waste heat, increasing the temperature inside the cooling device up to a first temperature range, and maintaining the temperature inside the cooling device within the first temperature range so that cold sensation provided to the user through the cold feedback is not degraded by a predetermined level or more.

1. Feedback Device

Hereinafter, a feedback device **100** according to an embodiment of the present disclosure will be described.

The feedback device **100** according to the embodiment of the present disclosure is a device configured to provide thermal feedback to a user. Specifically, the feedback device **100** may perform an exothermic operation or an endothermic operation and apply heat to the user or absorb heat from the user to provide thermal feedback to the user.

The feedback device **100** according to another embodiment of the present disclosure is a device configured to generate power and provide the power. Specifically, the feedback device **100** may generate an electromotive force through a temperature difference inside the feedback device **100** and provide power.

1.1. Operation of Feedback Device

1.1.1. Thermal Feedback

Thermal feedback is a type of a thermal stimulator that stimulates thermal sensation organs distributed across a user's body to make the user feel thermal sensation. In the present specification, thermal feedback should be interpreted as encompassing all thermal stimulators that stimulate a user's thermal sensation organs.

Representative examples of the thermal feedback include a hot feedback and a cold feedback. The hot feedback means the thermal feedback making the user feel a hot sensation by applying a "hot heat" or a positive heat to a hot spot on the user's skin. The cold feedback means the thermal feedback making the user feel a cold sensation by applying a "cold heat" or a negative heat to a cold spot on the user's skin. Here, because heat is a physical quantity expressed as a scalar, "cold heat is applied" may not be a precise expression in terms of physics. However, in the present specification, for convenience of description, a phenomenon in which heat is applied will be expressed as applying hot heat, and the opposite phenomenon, that is, a phenomenon in which heat is absorbed, will be expressed as applying cold heat.

In the present specification, thermal feedback may further include thermal grill feedback in addition to hot feedback and cold feedback. When hot heat and cold heat are simultaneously provided, a user perceives a sensation of pain instead of separately perceiving the hot sensation and cold sensation. Such a sensation is a so-called thermal grill illusion (TGI, hereinafter referred to as "heat pain"). That is, thermal grill feedback refers to thermal feedback in which hot heat and cold heat are applied in combination and may be mostly provided by outputting hot feedback and cold feedback simultaneously. Thermal grill feedback may also be referred to as heat pain feedback due to its aspect of providing a sensation close to a sensation of pain. Thermal grill feedback will be described in more detail below.

1.1.2 Power Generation

The feedback device **100** may generate power. The above-described thermal feedback may refer to an operation in which power is applied to a thermoelectric module **1000**, which will be described below, and an exothermic operation or an endothermic operation is performed. On the other hand, power generation may refer to an operation in which power is generated by a temperature difference in the thermoelectric module **1000**.

1.2. Application Example of Feedback Device

The above-described feedback device **100** may be implemented in various forms. Hereinafter, some of the typical implementations of the feedback device **100** will be mentioned.

1.2.1. Gaming Controller

A gaming controller is one of the typical implementations of the feedback device **100**. Here, a gaming controller may refer to an input unit that receives a user's manipulation in a game environment. A gaming controller is mostly linked to various devices for driving a game such as a game console device, a computer, a tablet, and a smartphone and serves to receive a user's manipulation used in the game. In a case of a portable game device, a gaming controller is integrally installed in the device itself.

Recently, a game environment has transformed from a traditional form in which a user's manipulation is reflected on a game screen output through a television (TV) or a monitor to virtual reality (VR) or augmented reality (AR) using a head mounted display (HMD) such as Oculus's Rift™ and Microsoft's HoloLens™. In the new game environment, beyond serving as a simple input unit, a gaming controller's role is being expanded to an output unit that provides various pieces of feedback to a user to increase user engagement in a game. As an example thereof, Dual Shock™ of Sony's PlayStation has a vibrating function for outputting tactile feedback to a user.

In the present specification, the feedback device **100** implemented as a gaming controller may provide thermal feedback to a user, thereby adding thermal sensation, which was conventionally not felt by the user, to a game as an interactive element and inducing higher engagement in the game.

1.2.2. Wearable Device

A wearable device **100***a* may be taken into consideration as another implementation of the feedback device **100**.

Here, the wearable device **100***a* may refer to a device worn on a user's body and configured to perform various functions. Following the recent trend to pursue more convenient technologies, an interest in human-machine interface (HMI) has gradually been increased, and various wearable devices **100***a* have been developed. By introducing a thermal feedback function to the wearable device **100***a*, a new user experience may be possible.

FIGS. **1** to **12** relate to the wearable device **100***a* among the implementations of the feedback device **100** according to an embodiment of the present disclosure.

The wearable device **100***a*, as its name implies, has been developed in various forms, which are capable of being worn on various parts of a user's body, such as a watch type **100***a*-**1** worn on a wrist as illustrated in FIG. **1**, a band type **100***a*-**2** illustrated in FIG. **2**, a wrist band (strap) type **100***a*-**3** illustrated in FIG. **3**, an arm band (arm sleeve) type **100***a*-**4** illustrated in FIG. **4**, a glove type **100***a*-**5** capable of being worn on a hand as illustrated in FIG. **5**, cap types **100***a*-**6** and **100***a*-**7** capable of being worn on a head as illustrated in FIGS. **6** and **7**, a scarf type **100***a*-**8** capable of being worn on a user's body as illustrated in FIG. **8**, a suit type **100***a*-**9** capable of being worn as clothing as illustrated in FIG. **9**, a vest type **100***a*-**10** capable of being worn by a user as illustrated in FIG. **10**, a shoe type **100***a*-**11** capable of being worn as a shoe as illustrated in FIG. **11**, and a sock type **100***a*-**12** capable of being worn as a sock as illustrated in FIG. **12**.

Like the above-described gaming controller, the wearable device **100***a* may also be designed to provide thermal feedback to a user through a portion in contact with the user's body. Referring to FIGS. **1** to **12**, in each of the forms of the wearable device **100***a*, a portion through which thermal feedback is provided to the user's body, that is, a contact surface **1600**, is marked. Positions of the contact surfaces **1600** are not limited by the drawings, and, in the wearable device **100***a*, the contact surfaces **1600** may also be disposed at portions different from those marked in the drawings.

1.2.3. Others

Although the gaming controller and the wearable device **100***a* among the implementations of the feedback device **100** have been described above, the implementations of the feedback device **100** are not limited thereto.

Actually, the feedback device **100** may be implemented as any device in which a thermal feedback function is usefully used. A few examples will be introduced to assist understanding. The feedback device **100** may be applied to a medical device for testing thermal sensation of a patient or may be applied to a steering wheel of a vehicle for a purpose of providing moderate warmth to a driver's hand or providing an alert signal. In addition, the feedback device **100** may be used in educational equipment to provide thermal sensation to a student and enhance and educational effect or may be used by being mounted at a seat of a movie theater to provide thermal sensation in addition to visual sensation to a user and enhance engagement in a movie.

1.3. Configuration of Feedback Device

Hereinafter, a configuration of the feedback device **100** according to an embodiment of the present disclosure will be described.

FIG. **13** is a block diagram of the configuration of the feedback device according to an embodiment of the present disclosure

Referring to FIG. **13**, the feedback device **100** may include a thermoelectric module **1000**, a heat radiator **2000**, and a liquid provider **3000**.

The thermoelectric module **1000** may output thermal feedback. Thermal feedback may be output by the thermoelectric module **1000** including a thermoelement connected to the contact surface **1600** applying hot heat or cold heat generated in the thermoelement following application of power thereto to the user's body through the contact surface **1600** coming into contact with the user's body. In the embodiment of the present disclosure, the thermoelectric module **1000** may perform an exothermic operation, an endothermic operation, or a thermal grill operation in response to a thermal feedback signal received from an external device, which is not the feedback device **100**, through a communication module (not illustrated) that performs communication with the external device and output thermal feedback, and the user may go through a thermal experience by the output thermal feedback. When a temperature difference occurs in the vicinity of the thermoelectric module **1000**, an electromotive force may be generated, and the thermoelectric module **1000** may use the electromotive force and provide power.

The heat radiator **2000** may indicate a configuration that dissipates waste heat generated in the thermoelectric module **1000** to the outside of the feedback device **100**. Here, the waste heat may refer to residual heat that remains after heat generated in the feedback device **100** is used to provide the thermal experience to the user. For example, residual heat that remains in the feedback device **100** after thermal feedback is output from the thermoelectric module **1000** may be included in the waste heat. The heat radiator **2000** will be described in more detail with reference to FIG. **28**.

The liquid provider **3000** may indicate a configuration provided to dissipate waste heat in the form of latent heat from the heat radiator **2000**. In the embodiment of the present disclosure, the liquid provider **3000** may provide a liquid to the heat radiator **2000**, and the liquid provided to the heat radiator **2000** may be vaporized by the waste heat transferred from the thermoelectric module **1000**. Due to the vaporization, a larger amount of waste heat may be dissipated to the outside. Due to the vaporization, the temperature of the feedback device **100** may drop. For example, the evaporated liquid may take heat away from a liquid that is provided to the heat radiator **2000** but not evaporated, and due to this, the temperature of the liquid that is provided to the heat radiator **2000** but not evaporated may be lowered. The liquid provider **3000** will be described in more detail with reference to FIG. **27**.

1.3.1 Thermoelectric Module

1.3.1.1. Outline of Thermoelectric Module

The thermoelectric module **1000** may perform an exothermic operation, an endothermic operation, or a thermal grill operation and output thermal feedback that transfers hot heat and cold heat to a user. To perform the above-described exothermic operation, endothermic operation, or thermal grill operation, the thermoelectric module **1000** may use a thermoelement such as a Peltier element.

The Peltier effect is a thermoelectric phenomenon discovered by Jean Peltier in 1834 and refers to a phenomenon in which, when two different metals are joined and then a current is applied, an exothermic reaction occurs at one side and a cooling reaction occurs at the other side depending on a direction of the current. The Peltier element is an element that causes the Peltier effect. Although the Peltier element was initially formed with an alloy of different metals such as bismuth and antimony, the Peltier element has recently been manufactured by a method in which an N type and P type semiconductor is arranged between two metal plates to have higher thermoelectric efficiency.

Because heat generation and heat absorption are immediately induced in metal plates at both sides of the Peltier element when a current is applied thereto, the heat generation and the heat absorption may be switched according to a direction of the current, and an extent of the heat generation or the heat absorption may be relatively precisely adjusted according to the amount of the current, the Peltier element is appropriate to be used in the exothermic operation or the endothermic operation for thermal feedback. Particularly, as a flexible thermoelement has recently been developed, the thermoelectric module **1000** may be manufactured in the form that is easy to come into contact with a user's body, and commercial usability of the feedback device **100** is enhanced.

Accordingly, as electricity is applied to the above-described thermoelement, the thermoelectric module **1000** may perform the exothermic operation or the endothermic operation. In terms of physics, an exothermic reaction and an endothermic reaction simultaneously occur in a thermoelement that received electricity. However, in the present specification, an operation of the thermoelectric module **1000** in which a surface in contact with a user's body generates heat will be defined as the exothermic reaction, and an operation of the thermoelectric module **1000** in which the surface absorbs heat will be defined as the endothermic operation. For example, the thermoelement may be configured by disposing an N type and P type semiconductor on a substrate **1220**. Here, when a current is applied, heat generation occurs at one side and heat absorption occurs at the other side. Here, when a side surface toward the user's body is referred to as a front surface, and a surface opposite the front surface is referred to as a rear surface, an operation of the thermoelectric module **1000** in which heat generation occurs at the front surface and heat absorption occurs at the rear surface may be defined as the exothermic operation, and conversely, an operation of the thermoelectric module **1000** in which heat absorption occurs at the front surface and heat generation occurs at the rear surface may be defined as the endothermic operation.

Because the thermoelectric effect is induced by a charge flowing in the thermoelement, electricity that induces the exothermic operation or the endothermic reaction of the thermoelectric module **1000** may be described in terms of a current. However, in the present specification, for convenience of description, the electricity will be collectively described in terms of a voltage. However, this is merely for convenience of description, and inventive thinking is not required for one of ordinary skill in the art to which the present disclosure pertains (hereinafter referred to as "person skill in the art") to change the description in terms of a voltage into description in terms of a current to interpret the description in terms of a voltage. Therefore, the present disclosure should not be limitedly interpreted in terms of a voltage.

The thermoelectric module **1000** may use a temperature difference in the thermoelectric module **1000** and provide power. The Seebeck effect is a thermoelectric phenomenon discovered by Thomas Johann Seebeck in 1821 and refers to a phenomenon in which, when different metal plates are joined and then a temperature difference is applied to the different metal plates, a thermal electromotive force is generated, causes electrons at a high temperature portion to have higher kinetic energy than the Fermi level and be diffused to a low temperature portion, and causes a potential difference, thereby providing power. The Seebeck element is an element that causes the Seebeck effect and, like the Peltier element, is manufactured by a method in which an N type and P type semiconductor is arranged between two metal plates. In the present specification, the thermoelectric module **1000** may be understood as a configuration capable of providing the above-described Peltier effect or Seebeck effect according to energy applied to the thermoelectric module **1000**.

1.3.1.2. Configuration of Thermoelectric Module

FIG. **14** is a block diagram of the configuration of the thermoelectric module according to an embodiment of the present disclosure.

Referring to FIG. **14**, the thermoelectric module **1000** may include the substrate **1220**, a thermoelectric pair array **1240**, the contact surface **1600**, a power terminal **1260**, a power storage **1270**, and a feedback controller **1400**.

The contact surface **1600** directly comes into contact with a user's body and transfers hot heat or cold heat generated in the thermoelectric module **1000** to the user's skin. In other words, a portion of an outer surface of the feedback device **100** directly or indirectly coming into contact with the user's body may be the contact surface **1600**. The contact surface **1600** may also be disposed at an inner surface of the feedback device **100**. For example, the contact surface **1600** may be formed at a grasping portion of a casing of the feedback device **100** grasped by the user. When the feedback device **100** is a wrist band type wearable device illustrated in FIG. **3**, an entire inner surface of the wrist band or a portion thereof may be the contact surface **1600**.

As an example, the contact surface **1600** may be provided in the form of a layer directly or indirectly attached to an outer surface (toward the user's body) of the thermoelectric pair array **1240** that performs the exothermic operation or the endothermic operation in the thermoelectric module **1000**. The contact surface **1600** in such a form may be disposed between the thermoelectric pair array **1240** and the user's skin and perform heat transfer. To facilitate the heat transfer from the thermoelectric pair array **1240** to the user's body, the contact surface **1600** may be formed of a material having high thermal conductivity. Also, the layer type contact surface **1600** may prevent the thermoelectric pair array **1240** from being directly exposed to the outside and prevent the thermoelectric pair array **1240** from an external impact.

Although the contact surface **1600** has been described above as a separate configuration disposed at the outer surface of the thermoelectric pair array **1240**, unlike this, the outer surface itself of the thermoelectric pair array **1240** may be the contact surface **1600**. In other words, an entire front surface of the thermoelectric pair array **1240** or a portion thereof may be the contact surface **1600**.

The substrate **1220** serves to support a unit thermoelectric pair **1241** and is formed of an insulating material. For example, ceramic may be selected as a material of the substrate **1220**. A flat plate may be used for the substrate **1220**, but the substrate **1220** is not necessarily formed of a flat plate.

The substrate **1220** may be formed of a flexible material having flexibility that may be universally used for various types of feedback devices **100** having various shapes of contact surfaces **1600**. For example, a portion at which the feedback device **100** comes into contact with a user is mostly curved in a wearable device type feedback device **100**, and for the thermoelectric module **1000** to be used at the curved portion, it may be important that the thermoelectric module **1000** has flexibility. Examples of flexible materials used for the substrate **1220** may include glass fiber, flexible plastic, or the like. According to circumstances, the substrate **1220** may not be included in the thermoelectric module **1000**. In this case, hot heat or cold heat generated in the thermoelectric pair array **1240** may be directly transferred to the contact surface **1600** without passing through the substrate **1220**.

The thermoelectric pair array **1240** includes a plurality of unit thermoelectric pairs **1241**. In an embodiment, the thermoelectric pair array **1240** may be disposed on the substrate **1220**. Although pairs of different metals (for example, bismuth and antimony) may be used as the unit thermoelectric pairs **1241**, pairs of an N-type semiconductor and a P-type semiconductor may be mainly used as the unit thermoelectric pairs **1241**.

In the unit thermoelectric pair **1241**, the pair of semiconductors are electrically connected to each other at one end and electrically connected to another unit thermoelectric pair **1241** at the other end. An electrical connection between a pair of semiconductors **1241***a* and **1241***b* or with an adjacent semiconductor pair may be performed by a conductor member **1242** disposed on the substrate **1220**. The conductor member **1242** may be a lead wire or an electrode formed of copper, silver, or the like.

The electrical connection between the unit thermoelectric pairs **1241** may be mainly performed by serial connection, the serially connected unit thermoelectric pairs **1241** may form a thermoelectric pair group **1250**, and the thermoelectric pair group **1250** may form the thermoelectric pair array **1240**.

The power terminal **1260** may apply power to the thermoelectric module **1000**. The thermoelectric pair array **1240** may generate heat or absorb heat according to a voltage value or a direction of a current of power applied to the power terminal **1260**. More specifically, two power terminals **1260** may be connected to a single thermoelectric pair group **1250**. Consequently, when a plurality of thermoelectric pair groups **1250** are present, two power terminals **1260** may be disposed for each of the thermoelectric pair groups **1250**. According to such a connection method, a voltage value or a direction of a current may be separately controlled for each of the thermoelectric pair groups **1250**, and whether to perform heat generation or heat absorption and an extent thereof may be adjusted.

As will be described below, the power terminal **1260** receives an electrical signal output by the feedback controller **1400**, and accordingly, as a result, the feedback controller **1400** may adjust a direction or magnitude of the electrical signal and control the exothermic operation and the endothermic operation of the thermoelectric module **1000**. When the plurality of thermoelectric pair groups **1250** are present, an electrical signal applied to each of the power terminals **1260** may be separately adjusted for each of the thermoelectric pair groups **1250**.

The power terminal **1260** may acquire power from the power storage **1270** or acquire power from an external power source.

The power storage **1270** may store power. Power stored in the power storage **1270** may be provided to the thermoelectric module **1000** through the power terminal **1260**. In an embodiment of the present disclosure, when heat is applied to the thermoelectric pair array **1240** and a temperature different occurs in the thermoelectric pair array **1240**, the thermoelectric pair array **1240** may generate power, and the power storage **1270** may store the power generated by the thermoelectric pair array **1240**.

The feedback controller **1400** may apply an electrical signal to the thermoelectric pair array **1240** through the power terminal **1260**. The feedback controller **1400** may apply a voltage to the thermoelement of the thermoelectric module **1000** and control the thermoelectric module **1000** to perform the exothermic operation or the endothermic operation. The feedback controller **1400** may also perform signal processing between an external device and the feedback device **100**. For example, the feedback controller **1400** may receive information on thermal feedback from an external device through the communication module (not illustrated), interpret the information on the thermal feedback, determine a type or intensity of the thermal feedback, generate an electrical signal according to a result of determination, and apply the generated electrical signal to the power terminal **1260** to allow the thermoelectric pair array **1240** to output the thermal feedback.

For this, the feedback controller **1400** may compute and process various pieces of information, output an electrical signal to the thermoelectric pair array **1240** according to a result of processing, and control an operation of the thermoelectric pair array **1240**. When power is generated by the thermoelectric pair array **1240**, the feedback controller **1400** may control the generated power. For example, the feedback controller **1400** may determine whether to store the generated power in the power storage **1270** or immediately supply the generated power from the thermoelectric pair array **1240** to the power terminal **1260**.

The feedback controller **1400** may be implemented with a computer or an apparatus similar thereto according to hardware, software, or a combination thereof. The feedback controller **1400** may be provided in the form of an electronic circuit that processes an electrical signal and performs a control function in terms of hardware and may be provided in the form of a program or code for driving a hardware circuit in terms of software.

A plurality of thermoelectric modules **1000** may be provided in the feedback device **100**. For example, when the feedback device **100** has a plurality of contact portions, the thermoelectric module **1000** may be mounted for each of the contact portions. When the plurality of thermoelectric modules **1000** is provided in a single feedback device **100** in this way, the feedback controller **1400** may be provided for each of the thermoelectric modules **1000** or a single feedback controller configured to collectively manage all of the thermoelectric modules **1000** may be provided in the feedback device **100**. When a plurality of feedback devices **100** are present, a single thermoelectric module **1000** or a plurality of thermoelectric modules **1000** may be disposed in each of the feedback devices **100**.

1.3.1.3 Form of Thermoelectric Module

Some typical forms of the thermoelectric module **1000** will be described on the basis of the above-described configuration of the thermoelectric module **1000**.

FIG. **15** is a view illustrating one form of the thermoelectric module according to an embodiment of the present disclosure.

Referring to FIG. **15**, in one form of the thermoelectric module **1000**, a pair of substrates **1220** are provided to face each other. The contact surface **1600** may be disposed at an outer side of one of the two substrates **1220** and transfer heat generated by the thermoelectric module **1000** to the user's body. When a flexible substrate **1220** is used as the substrate **1220**, flexibility may be imparted to the thermoelectric module **1000**.

The plurality of unit thermoelectric pairs **1241** are located between the substrates **1220**. Each of the unit thermoelectric pairs **1241** includes a pair of semiconductors that consist of an N-type semiconductor and a P-type semiconductor. In each of the unit thermoelectric pairs **1241**, one ends of the N-type semiconductor and the P-type semiconductor are electrically connected to each other by the conductor member **1242**. Also, unit elements are electrically connected by a method in which the other ends of an N-type semiconductor and a P-type semiconductor of any unit thermoelectric pair **1241** are connected to the other ends of a P-type semiconductor and an N-type semiconductor of an adjacent unit thermoelectric pair **1241** by the conductor member **1242**. Accordingly, the connected unit elements are serially connected and form a single thermoelectric pair group **1250**. In the present form, because an entire thermoelectric pair array **1240** is formed of a single thermoelectric pair group **1250**, and the entire unit thermoelectric pairs **1241** are serially connected between the power terminals **1260**, the thermoelectric module **1000** performs the same operation throughout front surfaces of the entire unit thermoelectric pairs **1241**. That is, the thermoelectric module **1000** may perform the exothermic operation when power is applied to the power terminal **1260** in one direction and may perform the endothermic operation when power is applied to the power terminal **1260** in the other direction.

FIG. **16** is a view illustrating another form of the thermoelectric module according to an embodiment of the present disclosure.

Referring to FIG. **16**, the other form of the thermoelectric module **1000** is similar to the above-described form. However, in the present form, the thermoelectric pair array **1240** has a plurality of thermoelectric pair groups **1250**, and each of the thermoelectric pair groups **1250** is connected to one of the power terminals **1260**. Accordingly, each of the thermoelectric pair groups **1250** may be separately controlled. For example, in FIG. **16**, currents in different directions may be applied to a first thermoelectric pair group **1250-1** and a second thermoelectric pair group **1250-2** so that the first thermoelectric pair group **1250-1** performs the exothermic operation (here, a direction of a current is "forward direction"), and the second thermoelectric pair group **1250-2** performs the endothermic operation (here, a direction of a current is "reverse direction"). As another example, different voltage values may be applied to the power terminal **1260** of the first thermoelectric pair group **1250-1** and the power terminal **1260** of the second thermoelectric pair group **1250-2** so that the first thermoelectric pair group **1250-1** and the second thermoelectric pair group **1250-2** perform the exothermic operation and the endothermic operation at different extents.

Although the thermoelectric pair groups **1250** are illustrated as being arranged in a one-dimensional array in the thermoelectric pair array **1240**, unlike this, the thermoelectric pair groups **1250** may also be arranged in a two-dimensional array.

FIG. **17** is a view illustrating still another form of the thermoelectric module according to an embodiment of the present disclosure. Referring to FIG. **17**, when the thermoelectric pair groups **1250** disposed in a two-dimensional array are used, operations of further divided regions may be separately controlled.

Although it has been described above that the pair of substrates **1220** facing each other are used in the above-described forms of the thermoelectric module **1000**, unlike this, a single substrate **1220** may be used.

FIG. **18** is a view illustrating yet another form of the thermoelectric module according to an embodiment of the present disclosure. Referring to FIG. **18**, the unit thermoelectric pair **1241** and the conductor member **1242** may be built in a single substrate **1220**. For this, glass fiber or the like maybe used for the substrate **1220**. When the single substrate **1220** having the above form is used, higher flexibility may be imparted to the thermoelectric module **1000**.

The above-described various forms of the thermoelectric module **1000** may be combined or modified within the self-evident scope by a person skilled in the art. For example, although the contact surface **1600** has been described as being formed as a separate layer from the thermoelectric module **1000** at the front surface of the thermoelectric module **1000** in each of the forms of the thermoelectric module **1000**, the front surface itself of the thermoelectric module **1000** may be the contact surface **1600**. For example, in one form of the above-described thermoelectric module **1000**, an outer surface of the substrate **1220** may be the contact surface **1600**.

1.3.1.4 Output of Thermal Feedback

Hereinafter, a thermal feedback output operation performed by the feedback device **100** will be described.

The feedback device **100** may output thermal feedback as the thermoelectric module **1000** performs the exothermic operation or the endothermic operation. The thermal feedback may include hot feedback, cold feedback, and thermal grill feedback.

Here, the hot feedback may be output by the thermoelectric module **1000** performing the exothermic operation. The cold feedback may be output by the thermoelectric module **1000** performing the endothermic operation. Also, the thermal grill feedback may be output by a thermal grill operation in which the exothermic operation and the endothermic operation are combined.

The feedback device **100** may output the above thermal feedback at various intensities. An intensity of thermal feedback may be adjusted by, for example, a method in which a level of a voltage applied to the thermoelectric pair array **1240** through the power terminal **1260** is adjusted by the feedback controller **1400** of the thermoelectric module **1000**. Here, the method of adjusting a level of a voltage includes a method in which a duty signal is smoothed and then power that is to be finally applied to the thermoelement is applied. That is, adjusting a level of a voltage by adjusting a duty rate of a duty signal should be understood as belonging to the adjusting of the level of a voltage.

Hereinafter, the exothermic operation, the endothermic operation, and the thermal grill operation will be described in more detail.

1.3.1.4.1 Exothermic/Endothermic Operation

The feedback device **100** may perform the exothermic operation with the thermoelectric module **1000** and provide hot feedback to the user. Similarly, the feedback device **100** may perform the endothermic operation with the thermoelectric module **1000** and provide cold feedback to the user.

FIG. **19** is a view illustrating an exothermic operation for providing hot feedback according to an embodiment of the present disclosure, and FIG. **20** is a graph related to an intensity of hot feedback according to an embodiment of the present disclosure.

Referring to FIG. **19**, the exothermic operation may be performed by inducing an exothermic reaction toward the contact surface **1600** as a current in a forward direction is applied to the thermoelectric pair array **1240** by the feedback controller **1400**. Here, when the feedback controller **1400** applies a predetermined voltage (hereinafter, a voltage that causes the exothermic reaction will be referred to as "forward voltage") to the thermoelectric pair array **1240**, the thermoelectric pair array **1240** starts the exothermic operation, and as illustrated in FIG. **20**, the temperature of the contact surface **1600** rises to a saturation temperature with time. Consequently, the user does not feel or only slightly feels hot sensation at an initial stage of the exothermic operation, feels an increase of the hot sensation until the temperature of the contact surface **1600** reaches the saturation temperature, and then receives hot feedback corresponding to the saturation temperature after a predetermined amount time elapses.

FIG. **21** is a view illustrating an exothermic operation for providing cold feedback according to an embodiment of the present disclosure, and FIG. **22** is a graph related to an intensity of cold feedback according to an embodiment of the present disclosure.

Referring to FIG. **21**, the endothermic operation may be performed by inducing an endothermic reaction toward the contact surface **1600** as a current in a reverse direction is applied to the thermoelectric pair array **1240** by the feedback controller **1400**. Here, when the feedback controller **1400** applies a predetermined voltage (hereinafter, a voltage that causes the endothermic reaction will be referred to as "reverse voltage") to the thermoelectric pair array **1240**, the thermoelectric pair array **1240** starts the endothermic operation, and as illustrated in FIG. **22**, the temperature of the contact surface **1600** drops to a saturation temperature with time. Consequently, the user does not feel or only slightly feels cold sensation at an initial stage of the endothermic operation, feels an increase of cold sensation until the temperature of the contact surface **1600** reaches the saturation temperature, and then receives cold feedback corresponding to the saturation temperature after a predetermined amount time elapses.

When power is applied to an thermoelement, in addition to an exothermic reaction and an endothermic reaction that occur at both sides of the thermoelement, electrical energy is converted into thermal energy, and heat is generated. Consequently, when a voltage at the same level is applied to the thermoelectric pair array **1240** with only a direction of a current changed, a temperature variation according to the exothermic operation may be higher than that according to the endothermic operation. Here, the temperature variation refers to a temperature difference between an initial temperature and a saturation temperature in a state in which the thermoelectric module **1000** is not operated.

Hereinafter, the exothermic operation and the endothermic operation performed by the thermoelement using electrical energy will be collectively referred to as "thermoelectric operation." Because the thermal grill operation, which will be described below, is an operation in which the exothermic operation and the endothermic operation are combined, the thermal grill operation may also be interpreted as a type of "thermoelectric operation."

1.3.1.4.2. Intensity Control of Exothermic/Endothermic Operation

When the thermoelectric module **1000** performs the exothermic operation or the endothermic operation as described above, the feedback controller **1400** may adjust a level of an applied voltage and control an extent of heat generation or an extent of heat absorption of the thermoelectric module **1000**. Consequently, in addition to the feedback controller **1400** adjusting a direction of a current and selecting a type of thermal feedback to be provided among hot feedback and cold feedback, an intensity of the hot feedback or the cold feedback may be adjusted by adjusting a level of a voltage.

FIG. **23** is a graph related to intensities of hot/cold feedback using voltage adjustment according to an embodiment of the present disclosure.

For example, referring to FIG. **23**, the feedback controller **1400** may apply five stages of voltage values in a forward direction or a reverse direction, and the feedback device **100** may provide a total of ten types of thermal feedback including five stages of hot feedback and five stages of cold feedback.

Here, although the hot feedback and the cold feedback are illustrated in FIG. **23** as having the same number of intensity grades, the numbers of intensity grades of the hot feedback and the cold feedback are not necessarily the same and may also be different from each other.

Here, although the hot feedback and the cold feedback are illustrated as being implemented by changing a direction of a current using a voltage value at the same level, a level of a voltage value applied for the hot feedback and a level of a voltage value applied for the cold feedback are not necessarily the same.

Particularly, when the same voltage is applied in performing the exothermic operation and the endothermic operation, because a temperature variation of the hot feedback according to the exothermic operation is generally higher than a temperature variation according to the endothermic operation, similar to that illustrated in FIG. **24**, a voltage higher than that applied for the same grade of hot feedback may be applied during cold feedback so that the same temperature variation is exhibited at intensity grades corresponding to each other. FIG. **24** is a graph related to hot/cold feedback having the same temperature variation according to an embodiment of the present disclosure.

When an intensity of thermal feedback is adjusted as described above, beyond simply providing hot sensation and cold sensation to a user, segmented thermal feedback such as strong hot sensation, weak hot sensation, strong cold sensation, and weak cold sensation may be provided. Such various segmented pieces of thermal feedback may allow a user to be more engaged in a game environment, a virtual/augmented reality environment, or the like, and when applied to a medical device, has an advantage of allowing a patient's sensation to be more precisely inspected.

1.3.1.4.3. Thermal Grill Operation

In addition to hot feedback and cold feedback, the feedback device **100** may provide thermal grill feedback. When a hot spot and a cold spot in a person's body are simultaneously stimulated, the person perceives a sensation of pain instead of perceiving hot sensation and cold sensation. The sensation of pain refers to heat pain. Consequently, the feedback device **100** may provide the thermal grill feedback to the user through the thermal grill operation in which the exothermic operation and the endothermic operation are performed in combination.

The feedback device **100** may perform the thermal grill operation using various methods for providing the thermal grill feedback. This will be described below after describing types of thermal grill feedback.

Thermal grill feedback may include neutral thermal grill feedback, hot heat grill feedback, and cold heat grill feedback.

Here, the include neutral thermal grill feedback, the hot heat grill feedback, and the cold heat grill feedback respectively causes a user to feel neutral heat pain, hot heat pain, and cold heat pain. The neutral heat pain refers to pain without warmth or coldness, the hot heat pain refers to pain in addition to warmth, and the cold heat pain refers to pain in addition to coldness.

The neutral heat pain is caused when intensities of warmth and coldness felt by the user correspond to a predetermined proportion range. A proportion in which a user feels the neutral heat pain (hereinafter referred to as "neutral proportion") may be different for each body part receiving thermal feedback and may be somewhat different even for the same body part depending on individuals. However, in most cases, the neutral heat pain tends to be felt in a situation in which an intensity of coldness is higher than an intensity of warmth.

Here, an intensity of thermal feedback may be a heat amount applied to a body part in contact with the contact surface **1600** or a heat amount absorbed from the corresponding body part by the feedback device **100**. Consequently, when thermal feedback is applied to a predetermined area for a predetermined amount of time, an intensity of thermal feedback may be expressed as a temperature difference value of hot sensation or cold sensation with respect to a temperature of a target portion to which the thermal feedback is applied.

The human body temperature is generally between 36.5° C. and 36.9° C., and the average human skin temperature is known to be about 30° C. to 32° C. although different for each individual or part. The skin temperature of the palm is about 33° C., which is slightly higher than the average human skin temperature. However, the above-mentioned temperature values may be somewhat different depending on individuals and may somewhat vary even for the same person.

According to an experiment example, it was confirmed that the neutral heat pain was felt when warmth of about 40° C. and coldness of about 20° C. were applied to a palm at 33° C. This is a case in which, with respect to the temperature of the palm, warmth that is 7° C. higher and coldness that is 13° C. lower are applied. Consequently, the neutral proportion in terms of temperature may correspond to 1.86.

As it can be confirmed from the above, in the case of most people, the neutral proportion expressed as a proportion of a temperature difference caused by coldness to a temperature difference caused by warmth with respect to skin, which is a subject of contact, when hot sensation and cold sensation are continuously applied to the same size of a region of one's body is in the range of about 1.5 to 5. The hot heat pain may be felt when a level of warmth is higher than the neutral proportion, and the cold heat pain may be felt when a level of coldness is higher than the neutral proportion.

In an embodiment of the present disclosure, the feedback device **100** may perform the thermal grill operation using a voltage adjustment method. The thermal grill operation using the voltage adjustment method may be applied to the feedback device **100** in which the thermoelectric pair array **1240** consists of the plurality of thermoelectric pair groups **1250**.

Specifically, the thermal grill operation using the voltage adjustment method may be performed by the feedback controller **1400** applying a forward voltage to some of the thermoelectric pair groups **1250** so that the exothermic operation is performed therein and applying a reverse voltage to the remaining thermoelectric pair groups **1250** so that the endothermic operation is performed therein and the thermoelectric module **1000** providing hot feedback and cold feedback simultaneously.

FIG. **25** is a view illustrating a thermal grill operation using a voltage adjustment method according to an embodiment of the present disclosure.

Referring to FIG. **25**, the thermoelectric pair array **1240** includes the plurality of thermoelectric pair groups **1250** disposed to form a plurality of lines. Here, the feedback controller **1400** may apply power so that first thermoelectric pair groups **1250-1** (for example, thermoelectric pair groups in odd-numbered lines) perform the exothermic operation and second thermoelectric pair groups **1250-2** (for example, thermoelectric pair groups in even-numbered lines) perform the endothermic operation. When the thermoelectric pair groups **1250** alternately perform the exothermic operation and the endothermic operation according to the arrangement of the lines as above, the user may simultaneously receive hot sensation and cold sensation, and as a result, may receive thermal grill feedback. Here, because differentiation between odd-numbered lines and even-numbered lines is arbitrary, the lines may be changed in an opposite manner.

Here, the feedback device **100** may control a saturation temperature according to the exothermic operations of the first thermoelectric pair groups **1250-1** and a saturation temperature according to the endothermic operations of the second thermoelectric pair groups **1250-2** to conform to a neutral proportion and provide neutral thermal grill feedback.

FIG. **26** is a table related to voltages for providing neutral thermal grill feedback in the voltage adjustment method according to an embodiment of the present disclosure.

For example, referring to FIG. **26**, when the feedback device **100**, in which the feedback controller **1400** may apply five forward voltages and five reverse voltages to the thermoelectric module **1000**, the thermoelectric module **1000** accordingly performs exothermic operations of five grades and endothermic operations of five grades, levels of temperature variations according to the exothermic operation and the endothermic operation of the same grade are the same, and levels of temperature variations between different grades of exothermic operations and endothermic operations are constant, is assumed, in a case in which a neutral proportion is set as 3, the feedback controller **1400** may apply a forward voltage of a first grade, which is a grade at which the level is the lowest, to the first thermoelectric pair group **1250-1** and apply a reverse voltage of a third grade to the second thermoelectric pair group **1250-2** so that the thermoelectric module **1000** may provide neutral heat pain feedback. Similarly, when the neutral proportion is set as 2.5, the feedback controller **1400** may apply a forward voltage of a second grade to the first thermoelectric pair group **1250-1** and apply a reverse voltage of a fifth grade to the second thermoelectric pair group **1250-2** to provide the neutral thermal grill feedback. Alternatively, when the neutral proportion is set as 4, the feedback controller **1400** may apply a forward voltage of a first grade to the first thermoelectric pair group **1250-1** and apply a reverse voltage of a fourth grade to the second thermoelectric pair group **1250-2** to generate the neutral thermal grill feedback. Alternatively, when the neutral proportion is set as 2, the feedback controller **1400** may apply a forward voltage of a first grade and a reverse voltage of a second grade or a forward voltage of a second grade and a reverse voltage of a fourth grade to provide neutral heat pain. Here, an intensity of the former neutral heat pain (the case in which the forward voltage of the first grade and the reverse voltage of the second grade are used) may be higher than an intensity of the latter neutral heat pain (the case in which the forward voltage of the second grade and the reverse voltage of the fourth grade are used). That is, the intensity adjustment is possible even in the case of thermal grill feedback. The above description on the method of providing neutral heat pain is merely illustrative, and the present disclosure is not limited thereto. For example, the number of grades of thermal feedback is not necessarily five, and the numbers of grades of cold heat and hot heat may also be different. Differences between temperature variations of different grades may not be constant. For example, differences between voltages of the grades may be constant.

The feedback controller **1400** may provide hot heat grill feedback by adjusting a forward voltage and a reverse voltage to reach a neutral proportion or lower or provide cold heat grill feedback by adjusting the forward voltage and the reverse voltage to reach a proportion higher than the neutral proportion.

For example, referring again to FIG. **26**, in the case in which the neutral proportion is set as 3, when the forward voltage of the first grade is applied to the first thermoelectric pair group **1250-1** and the reverse voltage of the first grade or the second grade is applied to the second thermoelectric pair group **1250-2**, because warmth and pain are generated in a lower proportion than the neutral proportion in the thermoelectric module **1000**, the feedback controller **1400** may provide the hot heat grill feedback in which warmth and pain are simultaneously felt to the user. Here, the forward voltage is not necessarily a forward voltage used in the neutral thermal grill feedback. In other words, the feedback controller **1400** may also use the forward voltage of the fourth grade and the reverse voltage of the fourth grade to allow the thermoelectric module **1000** to provide the hot heat grill feedback.

In the case of the cold heat grill feedback, in the case in which the neutral proportion is set as 3, the feedback controller **1400** may apply the forward voltage of the first grade and the reverse voltage of the fourth grade or the forward voltage of the first grade and the reverse voltage of the fifth grade to the thermoelectric module **1000**.

However, in a case in which the hot heat grill feedback or the cold heat grill feedback is attempted to be provided, because a problem in that the user does not feel pain occurs when the forward voltage and the reverse voltage are applied with a proportion significantly deviating from the neutral proportion, it may be preferable that a grade of the forward voltage/reverse voltage is adjusted to reach a proportion close to the neutral proportion.

1.3.2. Liquid Provider

FIG. **27** is a view for describing a liquid provider according to an embodiment of the present disclosure.

Referring to FIG. **27**, the liquid provider **3000** may refer to a configuration that provides a liquid to the heat radiator **2000**, which will be described below, so that waste heat is dissipated in the form of latent heat from the heat radiator **2000**. Here, the liquid may include any liquid such as water, alcohol, and methanol capable of absorbing the waste heat and being evaporated by the waste heat. The liquid may be evaporated when the amount of absorbed waste heat reaches unique vaporization heat of the liquid. That is, when the liquid is being evaporated, waste heat corresponding to the unique vaporization heat may be dissipated from the heat radiator **2000** to the outside of the feedback device **100**.

The liquid provider **3000** may include a liquid holder **3100**, and the liquid holder **3100** may hold a predetermined amount of liquid to provide a liquid to the heat radiator **2000**. A maximum amount of liquid that the liquid holder **3100** may hold may be determined according to performance of the liquid holder **3100**.

In an embodiment of the present disclosure, the liquid holder **3100** may include a liquid holding material, which is a material capable of holding a predetermined amount of liquid for a predetermined amount time. For example, the liquid holder **3100** may include SAP, which is a type of hydrogel. The SAP may indicate a polymer that absorbs a liquid following an introduction of a hydrophilic group to a three-dimensional network structure or a single structure through crosslinking between polymer chains. That is, the SAP may be a polymer having a large amount of hydrophilic groups and having a three-dimensional network structure or a single structure. The polymer may simultaneously have water insolubility and hydrophilicity.

Examples of the performance of the liquid provider **3000** include liquid absorption performance and liquid holding performance. The liquid absorption performance indicates a liquid absorption amount per unit mass of the liquid provider **3000**. For example, the SAP may absorb a liquid having a mass that is several tens to several hundreds times the mass of the SAP. The liquid holding performance indicates an extent to which the liquid provider **3000** holds a liquid instead of dissipating the liquid to the outside when a predetermined pressure is applied from the outside. When the liquid provider **3000** is the SAP, the liquid absorption performance and the liquid holding performance may be determined according to a crosslink density of the SAP. This is because the extent of crosslinking between polymer chains of the SAP is determined according to the crosslink density. That is, properties of the SAP are determined according to the crosslink density, and this will be described in more detail with reference to FIGS. **36** to **39**. In addition, the liquid holder **3100** may include another material having a liquid holding ability and a liquid releasing ability.

In an embodiment, the liquid provider **3000** may be physically separated from the feedback device **100**. As an example, the liquid provider **3000** may absorb a liquid in a state in which the liquid provider **3000** is separated from the feedback device **100**. The liquid provider **3000** may also be replaced with another liquid provider.

1.3.3. Heat Radiator

FIG. **28** is a view for describing a heat radiator according to an embodiment of the present disclosure.

Referring to FIG. **28**, the heat radiator **2000** may dissipate waste heat generated in the thermoelectric module **1000** to the outside of the feedback device **100**. As described above, the waste heat may refer to residual heat that remains after heat generated in the feedback device **100** is used to provide a thermal experience to the user. For example, residual heat that remains in the feedback device **100** after thermal feedback is output from the thermoelectric module **1000** may be included in the waste heat. When the amount of the waste heat is small, the waste heat does not affect the user. However, when the amount of the waste heat is a predetermined level or higher, components of the feedback device **100** may be degraded, and unnecessary hot sensation may be transferred to the user due to the waste heat and cause degradation of the thermal experience of the user. To solve the problems due to the waste heat, the heat radiator **2000** may dissipate the waste heat to the outside of the feedback device **100**.

In an embodiment of the present disclosure, the heat radiator **2000** may include a heat transferer **2100** and a heat dissipator **2200**. The heat transferer **2100** may be configured to receive waste heat from the thermoelectric module **1000** and transfer the waste heat to the **2200**, and the heat dissipator **2200** may dissipate the waste heat to the outside of the feedback device **100**.

In an embodiment of the present disclosure, the heat transferer **2100** and the heat dissipator **2200** may be implemented in various forms. In an embodiment, the heat transferer **2100** and the heat dissipator **2200** may be physically connected. For example, the heat transferer **2100** and the heat dissipator **2200** may directly come into contact, and the waste heat may be directly transferred from the heat transferer **2100** to the heat dissipator. As another example, the heat transferer **2100** and the heat dissipator **2200** may be connected through a physical medium. In this case, the waste heat may be transferred from the heat transferer **2100** to the heat dissipator **2200** via the medium. For example, the physical medium may be the liquid provider **3000**. In this case, even when the heat transferer **2100** and the heat dissipator **2200** are not connected, the waste heat may be transferred from the heat transferer **2100** to the heat dissipator **2200** through the liquid provider **3000**.

In another embodiment, the heat transferer **2100** and the heat dissipator **2200** may not be physically connected. In this case, the waste heat may be indirectly transferred from the heat transferer **2100** to the heat dissipator. For example, the waste heat may be transferred from the heat transferer **2100** through air.

In still another embodiment, the heat transferer **2100** and the heat dissipator **2200** may be integrally implemented. That is, the integrated type heat radiator **2000** may transfer the waste heat and dissipate the waste head.

In yet another embodiment, the heat radiator **2000** may include only the heat dissipator **2200**. In this case, the heat dissipator **2200** may acquire waste heat from the outside and then immediately dissipate the waste heat to the outside.

In this way, the heat transferer **2100** and the heat dissipator **2200** may be implemented in various embodiments, and although not mentioned, a configuration that transfers waste heat and/or dissipates the waste heat may be implemented as the heat radiator **2000**.

In an embodiment, the heat radiator **2000** may be physically separated from the feedback device **100**. For example, the heat radiator **2000** may be separated from the feedback device **100** and be replaced with another heat radiator.

2. Waste Heat Dissipation in Feedback Device

Hereinafter, waste heat dissipation of the feedback device **100** according to an embodiment of the present disclosure will be described.

2.1. Outline

As described above, when the thermoelectric module **1000** of the feedback device **100** performs a thermoelectric operation, waste heat may be generated. The waste heat may directly or indirectly affect a thermal experience of the user. As a specific example, FIG. **53** illustrates a graph related to a temperature of heat provided to a user from the feedback device **100** according to an embodiment of the present disclosure. For example, in the graph of FIG. **53**, the x-axis indicates time, the y-axis indicates temperature, and a line **5301** indicates temperature of the contact surface **1600** of the thermoelectric module **1000** with time.

In an embodiment of the present invention, the feedback device **100** may be operated as a cooling device that transfers cold sensation to the user. In this case, the thermoelectric pair array **1240** of the thermoelectric module **1000** may perform the endothermic operation and transfer cold heat to the contact surface **1600**. As the cold heat is transferred to the contact surface **1600**, the temperature of the contact surface **1600** may drop. Here, when waste heat is not generated, the temperature of the contact surface **1600** may be formed along a line **5302**, reach a minimum temperature in a section **5311**, and then maintain the minimum temperature in a section **5312**. However, as the thermoelectric pair array **1240** performs the endothermic operation, waste heat may be accumulated in the thermoelectric module **1000**, and due to an influence of the waste heat, the temperature of the contact surface may reach a minimum temperature and then rise, and be maintained within a predetermined temperature section **5322**. Accordingly, the minimum temperature of the contact surface **1260** in the case in which the waste heat is taken into consideration may be higher than that in the case in which the waste heat is not taken into consideration. When the waste heat is taken in to consideration, due to the waste heat, the temperature of the contact surface **1600** in the section **5312** may be higher than the minimum temperature in the section **5311**.

A difference between the temperature of the contact surface **1600** in the case in which the waste heat is taken into consideration and the temperature of the contact surface **1600** in the case in which the waste heat is not taken into consideration may vary according to how well the waste heat is dissipated from the feedback device **100**. For example, the temperature difference may be decreased when the waste heat is dissipated well from the feedback device **100**, and conversely, the temperature difference may be increased when the waste heat is not dissipated well from the feedback device **100**. Consequently, the ability of dissipating waste heat is an important factor in performance of the feedback device **100**. Hereinafter, a configuration of the feedback device **100** for improving the waste heat dissipation performance will be described in detail.

2.2. Waste Heat Dissipation Performance According to Waste Heat Transfer Path

2.2.1. Outline

A waste heat transfer path may be defined as a path from a spot at which waste heat is generated to a spot at which the waste heat is dissipated. In the feedback device **100** according to an embodiment of the present disclosure, the waste heat transfer path may refer to a path from the thermoelectric module **1000** in which waste heat is generated to the heat radiator **2000** through which the waste heat is dissipated. In this case, other elements such as the liquid provider **3000** may also be included in the waste heat transfer path according to a structure of the feedback device **100**.

In an embodiment of the present disclosure, the waste heat dissipation performance may be improved as the waste heat transfer path is shorter. This is because, under the assumption that all other conditions such as structures and materials of elements of a first feedback device and a second feedback device are the same, a longer waste heat transfer path may signify that the amount of time at which waste heat stays in the feedback device **100** is increased, and a shorter waste heat transfer path may signify that the amount of time at which waste heat stays in the feedback device **100** is decreased. Consequently, waste heat dissipation performance may vary according to a waste heat dissipation structure, and hereinafter, waste heat dissipation performance according to a waste heat transfer path will be described in detail.

2.2.2. Waste Heat Dissipation Path According to Various Embodiments

2.2.2.1. First Embodiment

FIG. **29** is a view illustrating a structure of the feedback device according to an embodiment of the present disclosure.

Referring to FIG. **29**, FIG. **29** illustrates a cross-sectional view of the feedback device **100** according to a first embodiment. In the feedback device **100**, the thermoelectric module **1000** and the heat radiator **2000** may be stacked in that order, and the liquid provider **3000** may be disposed inside the heat radiator **2000**. Here, a lower surface of the thermoelectric module **1000** may directly or indirectly come into contact with a user to provide thermal feedback to the user. For example, in a case in which the feedback device is a wrist band type wearable device as illustrated in FIG. **3**, when the wearable device is worn by the user, the thermoelectric module **1000** may be located at a portion coming into contact with the user, and the heat radiator **2000** may be located at a portion not coming into contact with the user. A portion of the heat radiator **2000** to which the waste heat is transferred may be the heat transferer **2100** (for example, a lower surface and a side surface of the heat radiator **2000**), and a portion at which the waste heat is evaporated in the form of latent heat may be the heat dissipator **2200** (for example, an upper surface of the heat radiator **2000**).

In an exemplary embodiment of the present disclosure, to prevent transfer of a liquid from the liquid provider **3000** to the thermoelectric module **1000**, a liquid blocking material (for example, a waterproof membrane, a waterproof film) may be disposed between the liquid provider **3000** and the thermoelectric module **1000**.

In the first embodiment, when the thermoelectric module **1000** performs the endothermic operation, cold heat may be transferred to the lower surface of the thermoelectric module **1000**, hot heat may be may be transferred to an upper surface of the thermoelectric module **1000**, and the hot heat may be waste heat that degrades a thermal experience of the user. In this case, the waste heat may be transferred from the thermoelectric module **1000** to the heat dissipator **2200** through the heat transferer **2100** and the liquid provider **3000**, and the waste heat may be dissipated from the heat dissipator **2200**. That is, the waste heat transfer path may be formed with the thermoelectric module **1000**, the heat transferer **2100**, the liquid provider **3000**, and the heat dissipator **2200**. Here, the liquid provider **3000** may provide a liquid contained in the liquid provider **3000** to the heat dissipator **2200**, and in the heat dissipator **2200**, the liquid received from the liquid provider **3000** may be evaporated due to the waste heat. Due to the evaporation of the liquid, the waste heat may be dissipated to the outside of the feedback device **100**.

In an embodiment of the present disclosure, depending on its material, the heat dissipator **2200** may have liquid transfer directionality in a specific direction. For example the heat dissipator **2200** may have liquid transfer directionality in a vertical direction or may have liquid transfer directionality in a horizontal direction. In the first embodiment, a liquid may be transferred from a lower end of the heat dissipator **2200** to the heat dissipator **2200**. Accordingly, in the first embodiment, the heat dissipator **2200** having the liquid transfer directionality in the vertical direction may be beneficial in terms of improving the waste heat dissipation performance.

In an embodiment of the present disclosure, depending on its material, the heat dissipator **2200** may have evaporation directionality in a specific direction. For example, the heat dissipator **2200** may have evaporation directionality in an upper direction or may have evaporation directionality in a side direction. In the first embodiment, evaporation of a liquid may occur from an upper end of the heat dissipator **2200** toward the air. Accordingly, in the first embodiment, the heat dissipator **2200** having the evaporation directionality in the upper direction may be beneficial in terms of improving the waste heat dissipation performance.

In the structure according to the first embodiment, the length of the waste heat transfer path may vary depending on the thickness of the liquid provider **3000**. For example, in an example shown in FIG. **29**, a waste heat transfer path in a case in which the thickness of the liquid provider **3000** is a may be shorter than that in a case in which the thickness of the liquid provider **3000** is b. As the waste heat transfer path is shortened, the amount of time during which the waste heat stays in the liquid provider **3000** may be shortened, and due to this, the waste heat dissipation performance of the feedback device **100** may be improved.

In an embodiment, when the thickness of the liquid provider **3000** becomes smaller, the amount of a liquid contained in the liquid provider **3000** may be reduced. When the liquid provider **3000** runs out of liquid, the liquid provider **3000** has to be supplemented with a liquid. As the thickness of the liquid provider **3000** becomes smaller, a time taken for the liquid provider **3000** to run out of liquid may also be shortened. That is, the waste heat dissipation performance of the feedback device **100** and the liquid holding performance of the liquid provider **3000** may be traded off for each other according to the thickness of the liquid provider **3000**.

2.2.2.2. Second Embodiment

FIG. **30** is a view illustrating a structure of the feedback device according to another embodiment of the present disclosure.

Referring to FIG. **30**, FIG. **30** illustrates a cross-sectional view of the feedback device **100** according to a second embodiment. In the second embodiment, the thermoelectric module **1000** and the heat radiator **2000** may be stacked in that order in the feedback device **100**, and unlike the first embodiment, liquid providers **3000**-*a* and **3000**-*b* may be disposed at both side surfaces of the heat radiator **2000**. A supporter **5000** may be disposed at a side surface of the thermoelectric module **1000**, and the liquid providers **3000**-*a* and **3000**-*b* may be disposed at an upper end of the supporter **5000**. Here, the supporter **5000** may be configured to support at least one of the thermoelectric module **1000**, the heat radiator **2000**, and the liquid providers **3000**-*a* and **3000**-*b*. In an exemplary embodiment of the present disclosure, the supporter **5000** may block heat generated from the thermoelectric module **1000** instead of transferring the heat to the user. The supporter **5000** may block a liquid released from the liquid providers **3000**-*a* and **3000**-*b* instead of transferring the liquid to the user. The supporter **5000** may be disposed to come into contact with the user.

Although the case in which the heat transferer **2100** and the heat dissipator **2200** are integrally formed with the heat radiator **2000** is illustrated in FIG. **30**, the embodiment is not limited thereto, and the heat transferer **2100** and the heat dissipator **2200** may also be separately formed in the heat radiator **2000**. Although the case in which heights of the liquid providers **3000**-*a* and **3000**-*b* are higher than a height of the heat radiator **2000** is illustrated in FIG. **30**, the embodiment is not limited thereto, and the heights of the liquid providers **3000**-*a* and **3000**-*b* may be lower than or equal to the height of the heat radiator **2000**.

In the second embodiment, because the liquid providers **3000**-*a* and **3000**-*b* do not come into contact with an upper portion of the thermoelectric module **1000**, the liquid providers **3000**-*a* and **3000**-*b* may not receive waste heat from the thermoelectric module **1000**. Accordingly, waste heat may be directly transferred from the thermoelectric module **1000** to the heat radiator **2000**, and the waste heat transfer path may be formed with the thermoelectric module **1000** and the heat radiator **2000**. Accordingly, the waste heat transfer path may be shortened in comparison to when the liquid providers **3000**-*a* and **3000**-*b* are included in the waste heat transfer path, and due to this, the waste heat dissipation performance may be improved.

In the second embodiment, because the liquid providers **3000**-*a* and **3000**-*b* are disposed at the side surfaces of the heat radiator **2000**, the heat radiator **2000** may receive a liquid from the liquid providers **3000**-*a* and **3000**-*b* through the side surfaces. Here, because the heat radiator **2000** receives waste heat from the thermoelectric module **1000** through an entire region of the heat radiator **2000**, waste heat needs to be dissipated through the entire region of the heat radiator **2000**. Consequently, because a liquid may be transferred to a central portion of the heat radiator when the heat radiator **2000** has the liquid transfer directionality in the horizontal direction, in the second embodiment, the heat radiator **2000** having the liquid transfer directionality in the horizontal direction may be beneficial in terms of improving the waste heat dissipation performance.

However, according to the embodiment, because the liquid providers **3000**-*a* and **3000**-*b* are disposed at the side surfaces of the heat radiator **2000**, a larger amount of liquid may be transferred to an outer region of the heat radiator **2000** than to the central region thereof. In this case, during the same amount of time, the amount of waste heat dissipated from the outer region that contains a larger amount of liquid may be larger than the amount of waste heat dissipated from the central region. When the heat radiator **2000** has high liquid transfer directionality in the horizontal direction or a liquid is transferred from the liquid providers **3000**-*a* and **3000**-*b* to the heat radiator **2000** for a long time such that the liquid content in the central region of the heat radiator **2000** and the liquid content in the outer region of the heat radiator **2000** are similar, the amount of waste heat dissipated from the outer region and the amount of waste heat dissipated from the central region may also be similar.

2.2.2.3. Third Embodiment

FIG. **31** is a view illustrating a structure of the feedback device according to still another embodiment of the present disclosure.

Referring to FIG. **31**, FIG. **31** illustrates a cross-sectional view of the feedback device **100** according to a third embodiment. In the third embodiment, the thermoelectric module **1000** and the heat radiator **2000** may be stacked in that order in the feedback device **100**, the supporter **5000** may be disposed at the side surface of the thermoelectric module **1000**, and the liquid provider **3000** may be disposed at an upper end of the supporter **5000** and a side surface of the heat radiator **2000**. However, unlike the second embodiment, the liquid provider **3000** may be disposed only at one side surface of the heat radiator **2000**.

In the third embodiment, like the second embodiment, the liquid provider **3000** does not come into contact with the upper portion of the thermoelectric module **1000** and thus may not receive waste heat from the thermoelectric module **1000**. Accordingly, the waste heat transfer path may be formed with the thermoelectric module **1000** and the heat radiator **2000**, the waste heat transfer path may be shortened in comparison to when the liquid provider **3000** is included in the waste heat transfer path, and due to this, the waste heat dissipation performance may be improved.

In the third embodiment, because the liquid provider **3000** is disposed at only one side surface of the heat radiator **2000**, a liquid may be transferred from the one side surface to the other side surface of the heat radiator **2000**. However, because the heat radiator **2000** receives waste heat from the thermoelectric module **1000** through an entire region thereof, waste heat needs to be dissipated through the entire region thereof. Consequently, for the waste heat to be effectively dissipated through the other side surface instead of the one side surface coming into contact with the liquid provider **3000**, the heat radiator **2000** may have to have the liquid transfer directionality in the horizontal direction.

According to the embodiment, because the liquid provider **3000** is disposed at only one side surface of the heat radiator **2000**, a larger amount of liquid may be transferred to the one side surface of the heat radiator **2000** in comparison to the other side surface thereof. In this case, during the same amount of time, the amount of waste heat dissipated from the one side surface may be larger than the amount of waste heat dissipated from the other side surface. When the heat radiator **2000** has high liquid transfer directionality in the horizontal direction or a liquid is transferred from the liquid provider **3000** to the heat radiator **2000** for a long time such that the liquid content in the one side surface of the heat radiator **2000** and the liquid content in the other side surface of the heat radiator **2000** are similar, the amount of waste heat dissipated from the one side surface and the amount of waste heat dissipated from the other side surface may also be similar.

2.2.2.4. Fourth Embodiment

FIG. **32** is a view illustrating a structure of the feedback device according to yet another embodiment of the present disclosure;

Referring to FIG. **32**, FIG. **32** illustrates a cross-sectional view of the feedback device **100** according to a fourth embodiment. In the fourth embodiment, the thermoelectric module **1000**, the liquid providers **3000**-*a* and **3000**-*b*/the heat radiator **2000** may be disposed in that order in the feedback device **100**, and particularly, the liquid providers **3000**-*a* and **3000**-*b* may be disposed at portions of side surfaces and portions of a lower surface of the heat radiator **2000**.

Unlike the previous embodiments, in the fourth embodiment, the waste heat transfer path may include two paths. For example, a first waste heat transfer path may be formed with the thermoelectric module **1000**, the liquid providers **3000**-*a* and **3000**-*b*, and the heat radiator **2000**, and a second waste heat transfer path may be formed with the thermoelectric module **1000** and the heat radiator **2000**. In the second waste heat transfer path, some of the waste heat may be transferred to the heat radiator **2000** through the liquid providers **3000**-*a* and **3000**-*b*. Accordingly, unlike the second and third embodiments, the length of the second waste heat transfer path may vary depending on thicknesses of the liquid providers **3000**-*a* and **3000**-*b*. However, because the liquid providers **3000**-*a* and **3000**-*b* are disposed inside the heat radiator **2000**, the amount of liquid transferred to the heat radiator **2000** may be increased in comparison to when the liquid providers **3000**-*a* and **3000**-*b* are disposed at the side surfaces, and accordingly, the waste heat dissipation performance may be improved. The heat radiator **2000** may receive a liquid from the liquid providers **3000**-*a* and **3000**-*b* through the lower end thereof as well as the side surfaces thereof. Consequently, when the heat radiator **2000** simultaneously has the liquid transfer directionality in the horizontal direction and the liquid transfer directionality in the vertical direction, the waste heat dissipation performance may be further improved.

2.2.2.5 Fifth Embodiment

FIG. **33** is a view illustrating a structure of the feedback device according to yet another embodiment of the present disclosure.

Referring to FIG. **33**, FIG. **33** illustrates a cross-sectional view of the feedback device **100** according to a fifth embodiment. In the fifth embodiment, as the first embodiment illustrated in FIG. **29**, the thermoelectric module **1000** and the heat radiator **2000** may be stacked in that order in the feedback device **100**, and the liquid provider **3000** may be disposed inside the heat radiator **2000**.

Here, in the fifth embodiment, a protector **2500** may be disposed on the heat radiator **2000**. Here, the protector **2500** may be configured to protect the feedback device **100** from the outside.

In an embodiment of the present disclosure, the protector **2500** may be disposed in the form of surrounding the heat radiator **2000**, and a predetermined space may be disposed between the protector **2500** and the heat radiator **2000**. The protector **2500** may be formed of various materials. For example, the protector **2500** may be formed of a material that does not absorb a liquid, such as plastic net and silicone.

Specifically, the heat radiator **2000** may become wet due to a liquid provided from the liquid provider **3000**, and when, in this situation, a user's hand touches the heat radiator **2000**, the user's hand may become wet due to the liquid. However, when the protector **2500** is disposed in the feedback device **100**, the user's hand may not touch the heat radiator **2000** due to the protector **2500**. Thus, convenience of the user may be improved.

Because the predetermined space is disposed inside the protector **2500**, the waste heat dissipation path in the fifth embodiment may be formed with the thermoelectric module **1000**, the heat transferer **2100**, the liquid provider **3000**, and the heat dissipator **2200** as in the first embodiment, and the waste heat dissipation performance in the first embodiment may also be maintained in the fifth embodiment.

Although the structure which is the same as the first embodiment, except that the protector **2500** is applied, is illustrated in FIG. **33**, the embodiment is not limited thereto, and the protector **2500** of the fifth embodiment may also be applied to any of the above-described second embodiment to fourth embodiment.

2.2.2.6 Sixth Embodiment

FIG. **34** is a view illustrating a structure of the feedback device according to yet another embodiment of the present disclosure.

Referring to FIG. **34**, FIG. **34** illustrates a cross-sectional view of the feedback device **100** according to a sixth embodiment. In the sixth embodiment, as the first embodiment illustrated in FIG. **29**, the thermoelectric module **1000** and the heat radiator **2000** may be stacked in that order in the feedback device **100**, and the liquid provider **3000** may be disposed inside the heat radiator **2000**.

Here, unlike the first embodiment, a second liquid provider **3500** may be included inside the heat radiator **200**. The second liquid provider **3500** may be configured to provide a liquid to the liquid provider **3000** in addition to the heat radiator **2000**. For this, the second liquid provider **3500** may be formed of a material having an improved liquid absorbing ability than the liquid provider **3000**. For example, the second liquid provider **3500** may be formed of a material having high liquid absorption performance such as sponge or may be formed of a SAP. Here, when both the second liquid provider **3500** and the liquid provider **3000** are formed of the SAPs, a liquid absorbing ability of the SAP constituting the second liquid provider **3500** may be higher than a liquid absorbing ability of the SAP constituting the liquid provider **3000**.

In an embodiment, the liquid provider **3000** may receive a liquid from the outside and absorb the received liquid. Depending on liquid absorption performance of the liquid provider **3000**, a somewhat long time may be taken for the liquid provider **3000** to absorb the received liquid. In this case, the liquid provider **3000** may have to continuously receive a liquid from the outside until a predetermined amount of liquid is held herein, and in some embodiments, the feedback device **100** may not be usable while the liquid provider **3000** receives a liquid from the outside. Here, when the second liquid provider **3500** is included in the feedback device **100**, because the liquid absorbing ability of the second liquid provider **3500** is higher than that of the liquid provider **3000**, the second liquid provider **3500** may hold the predetermined amount of liquid within a shorter amount of time than the amount of time taken for the liquid provider **3000** to hold the predetermined amount of liquid. Accordingly, the second liquid provider **3500** may provide the predetermined amount of liquid to the liquid provider **3000**. That is, even when a liquid is not provided from the outside, the liquid provider **3000** may absorb a liquid from the second liquid provider **3500**. In other words, when the second liquid provider **3500** is included in the feedback device **100**, the amount of time taken for the liquid provider **3000** to receive a liquid from the outside may be reduced due to the liquid absorbing ability of the second liquid provider **3500**, and because of this, the amount of time during which the feedback device **100** is usable may be increased.

Because the second liquid provider **3500** is included in the feedback device **100**, the overall amount of liquid held in the feedback device **100** may be increased. Accordingly, the feedback device **100** may dissipate waste heat to the outside for a longer time in comparison to when the second liquid provider **3500** is not included in the feedback device **100**.

Although the structure which is the same as the first embodiment, except that the second liquid provider **3500** is applied, is illustrated in FIG. **34**, the embodiment is not limited thereto, and the second liquid provider **3500** of the sixth embodiment may also be applied to any of the above-described second embodiment to fifth embodiment.

Although examples of the waste heat dissipation path and the waste heat dissipation performance according to the waste heat transfer path are described herein using the first embodiment to the sixth embodiment, the spirit of the present disclosure is not limited thereto, and various other embodiments in which waste heat is transferred may also be applied to the spirit of the present disclosure.

2.3. Waste Heat Dissipation Performance According to Characteristics of Each Element of Feedback Device

2.3.1. Waste Heat Dissipation Performance According to Characteristics of Liquid Provider

In an embodiment of the present disclosure, the liquid provider **3000** may provide a liquid to the heat radiator **2000**, and the amount of liquid provided to the heat radiator **200** and the speed at which the liquid is provided may directly affect the waste heat dissipation performance of the feedback device **100**. The amount of liquid provided to the heat radiator **200** by the liquid provider **3000** and the speed at which the liquid is provided may be determined according to characteristics of the liquid provider. Hereinafter, the waste heat dissipation performance of the feedback device **100** according to the characteristics of the liquid provider **3000** will be described in detail.

2.3.1.1. Waste Heat Dissipation Performance According to Liquid Content

FIG. **35** is a view for describing waste heat dissipation performance according to liquid content in the liquid provider according to an embodiment of the present disclosure.

Referring to FIG. **35**, a graph of FIG. **35** represents power generation efficiency depending on mass of a SAP. The liquid holder **3100** of the liquid provider **3000** may include a liquid holding material, and the amount of liquid that the liquid provider **3000** may hold may vary depending on mass of the liquid holding material. For example, when the liquid holder **3100** is a SAP, an overall amount of liquid contained in the liquid provider **3000** may vary depending on the mass of the SAP. The waste heat dissipation performance may also vary depending on the amount of liquid contained in the liquid provider **3000**.

Specifically, in the graph of FIG. **35**, the x-axis indicates time (minutes), and the y-axis indicates a voltage (mV) generated in the feedback device **100**. In the graph of FIG. **35**, a trend **3501** may indicate power generation efficiency of the feedback device **100** when the mass of the polymer resin is 0.1 g, a trend **3502** may indicate power generation efficiency of the feedback device **100** when the mass of the polymer resin is 0.5 g, and a trend **3503** may indicate power generation efficiency of the feedback device **100** when the mass of the polymer resin is 1.0 g. In the graph of FIG. **35**, it may be confirmed that the power generation amount is higher in the trend **3503** than in the trend **3501**. This may signify that the temperature difference in the thermoelectric module **1000** increases as the mass of the polymer resin is higher. The increase in the temperature difference in the thermoelectric module **1000** may indicate an improvement in the waste heat dissipation performance in the feedback device **100**. Consequently, the graph of FIG. **35** may indicate that the waste heat dissipation performance is improved as the mass of the polymer resin is higher. Also, it is confirmed that the waste heat dissipation performance of the feedback device **100** may be enhanced as the liquid content in the liquid provider **3000** is higher.

2.3.1.2. Waste Heat Dissipation Performance According to Liquid Absorption Performance and Liquid Holding Performance

FIG. **36** is a view for describing liquid absorption performance and liquid holding performance according to a crosslink density of the liquid provider according to an embodiment of the present disclosure.

Referring to FIG. **36**, (a) represents a liquid provider **3000-36*a*** including a SAP having a low crosslink density, and (b) represents a liquid provider **3000-36*b*** including a SAP having a high crosslink density. As described above, liquid absorption performance and liquid holding performance may be determined according to a crosslink density. Specifically, in the case of the liquid provider **3000-36***a*, due to having a low crosslink density, a crosslinking extent between polymer chains of the SAP may be low. Accordingly, because the amount of liquid that may be contained in the polymer chain increases, the liquid absorption performance of the liquid provider **3000-36***a* may be improved. Conversely, when a pressure is applied to the polymer chain, because a crosslinking extent of the polymer chains is low, the liquid contained in the polymer chain may be easily released, and because of this, the liquid holding performance of the liquid provider **3000-36***a* may be degraded.

Conversely, in the case of the liquid provider **3000-36***b*, due to having a high crosslink density, a crosslinking extent between polymer chains of the SAP may be high. Accordingly, because it is difficult for the polymer chain to hold a large amount of liquid, the liquid absorption performance of the liquid provider **3000-36***b* is degraded. Because the polymer chain becomes sturdier, a liquid contained in the polymer chain may not be easily released even when a pressure is applied to the polymer chain. Accordingly, the liquid holding performance of the liquid provider **3000-36***b* may be improved. To sum up, the liquid absorption performance and the liquid holding performance of the liquid provider **3000** may be traded off for each other according to a crosslink density.

FIG. **37** is a view for describing waste heat dissipation performance according to the liquid absorption performance and the liquid holding performance according to an embodiment of the present disclosure.

Referring to FIG. **37**, (a) is a graph illustrating power generation efficiency according to a crosslink density, and (b) is a table showing values in the graph.

In the graph of (a), the x-axis indicates time (minutes), and the y-axis indicates a power density ($\mu W/cm^2$) indicating a power generation amount per unit area generated in the feedback device **100**. In the graph of (a), a line **3701** indicates a power density of power output from the feedback device **100** when the liquid provider **3000** includes the SAP having a high crosslink density, and a line **3702** indicates a power density of power output from the feedback device **100** when the liquid provider **3000** includes the SAP having a low crosslink density. As shown in the graph of (a) and the table of (b), power generation efficiency of the feedback device **100** when the SAP has a low crosslink density may be higher than power generation efficiency of the feedback device **100** when the SAP has a high crosslink density. This may signify that the temperature difference in the thermoelectric module **1000** increases as the crosslink density is lower. The increase in the temperature difference in the thermoelectric module **1000** may indicate an improvement in the waste heat dissipation performance in the feedback device **100**. That is, it may be confirmed that the waste heat dissipation performance of the feedback device **100** is improved as the crosslink density is lower. This is because, due to the liquid absorption performance being improved and the liquid holding performance being degraded as the crosslink density is lower, the amount of liquid transferred to the heat radiator **2000** is increased.

FIG. **38** is a view for describing liquid absorption performance and liquid holding performance according to a crosslink density of the liquid provider according to another embodiment of the present disclosure.

Referring to FIG. **38**, in (a) and (b), a crosslink density of the liquid provider **3000** may be divided into two regions. In (a), a first region **3000-38***a***1** of a liquid provider **3000-38***a* may be formed of a polymer resin having a low crosslink density, and a second region **3000-38***a***2** thereof may be formed of a polymer resin having a high crosslink density. Accordingly, a lower region of the liquid provider **3000-38***a* may have high liquid absorption performance and low liquid holding performance, and an upper region thereof may have low liquid absorption performance and high liquid holding performance.

Conversely, in (b), a first region **3000-38***b***1** of a liquid provider **3000-38***b* may be formed of a polymer resin having a low crosslink density, and a second region **3000-38***b***2** thereof may be formed of a polymer resin having a high crosslink density. Accordingly, a lower region of the liquid provider **3000-38***b* may have low liquid absorption performance and high liquid holding performance, and an upper region thereof may have high liquid absorption performance and low liquid holding performance.

In (b), the second region **3000-38***b***2** of the liquid provider **3000-38***b* may serve as the second liquid provider **3500** described with reference to FIG. **34**. This may be due to the second region **3000-38***b***2** having higher liquid absorption performance than that of the first region **3000-38***b***1**. Accordingly, the first region **3800-38***b***1** may receive a liquid from the second region **3000-38***b***2** even when a liquid is not provided from the outside. Accordingly, because an amount of time taken for the liquid provider **3800-38***b* to receive a liquid from the outside is reduced, an amount of time during which the feedback device **100** is available may be increased.

In an embodiment of the present disclosure, when liquid absorption performance is high and liquid holding performance is low as in the regions **3000-38***a***1** and **3000-38***b***2**, disposing the heat radiator **2000** to come into contact with the regions **3000-38***a***1** and **3000-38***b***2** may be beneficial in terms of liquid transfer.

When liquid absorption performance is low and liquid holding performance is high as in the regions **3000-38***a***2** and **3000-38***b***1**, a liquid may not be easily released to the outside of the liquid providers **3000-38***a* and **3000-38***b*. Accordingly, when the regions **3000-38***a***2** and **3000-38***b***1** are disposed at regions that are easy to come into contact with a user, because a liquid is not transferred to the user, the user may not feel discomfort even when the user's body comes into contact with the regions **3000-38***a***2** and **3000-38***b***1**.

Although the region of the liquid provider is divided into upper and lower regions according to crosslink densities in FIG. **38**, embodiments are not limited thereto, and the region of the liquid provider may also be divided into left and right regions or may be divided into three or more regions.

FIG. **39** is a view for describing liquid absorption performance and liquid holding performance according to a crosslink density of the liquid provider according to still another embodiment of the present disclosure.

Referring to FIG. **39**, in (a) and (b), each of liquid providers **3000-39***a* and **3000-39***b* may be divided into two regions according to crosslink densities. In (a), a second region **3000-39***a***2** of the liquid provider **3000-39***a* may surround a first region **3000-39***a***1** thereof. Here, the first region **3000-39***a***1** may be formed of polymer resin having a low crosslink density, and the second region **3000-39***a***2** may be formed of polymer resin having a high crosslink density. Accordingly, an inner region of the liquid provider **3000-39***a* may have high liquid absorption performance and low liquid holding performance, and an outer region thereof may have low liquid absorption performance and high liquid holding performance.

In this case, because the inner region holds a large amount of liquid, and the outer region does not easily release a liquid, the liquid provider **3000-39***a* may continuously hold a liquid. When the amount of waste heat generated in the feedback device **100** is small, the liquid provider **3000-39***a* may provide a liquid sufficient for dissipating the waste heat to the heat radiator **2000**. Consequently, in this case, the waste heat dissipation effect of the feedback device **100** may be improved, and use time of the feedback device **100** may also be increased.

Conversely, in (b), a second region **3000-39***b***2** may surround a first region **3000-39***b***1** as in (a). Here, the first region **3000-39***b***1** of a liquid provider **3000-39***b* may be formed of polymer resin having a high crosslink density, and the second region **3000-39***b***2** may be formed of polymer resin having a low crosslink density. Accordingly, an inner region of the liquid provider **3000-39***b* may have low liquid absorption performance and high liquid holding performance, and an outer region thereof may have high liquid absorption performance and low liquid holding performance.

In this case, because the inner region does not easily release a liquid, and the outer region holds a large amount of liquid, a large amount of liquid may be provided to the heat radiator **2000** at an initial stage, and the amount of liquid being transferred to the heat radiator **2000** may be gradually decreased. This may be beneficial for heat dissipation of the feedback device **100** in a case in which cold feedback is intensively performed at an initial stage and a large amount of waste heat is accumulated at the initial stage.

2.3.1.3. Waste Heat Dissipation Performance According to Liquid Permeability

FIG. **40** is a view for describing liquid transfer according to liquid permeability of the liquid provider according to an embodiment of the present disclosure.

Referring to FIG. **40**, liquid permeability may vary according to a configuration of the liquid provider **3000**. Here, liquid permeability may be defined as a physical property that indicates an extent to which a liquid is transferred between polymer resins when the polymer resins have a liquid absorbed thereinto and are swelled.

In a case shown in (a), polymer resins of the liquid provider **3000** may have relatively uniform volumes. Because the volumes of the polymer resins are uniform, an empty space between the polymer resins may be reduced. Because of this, it may be difficult for a liquid to pass through portions between the polymer resins, and liquid permeability may be decreased.

In a case shown in (b), polymer resins of the liquid provider **3000** may not have uniform volumes. For example, a polymer resin having a small volume may be disposed between polymer resins having a large volume. In this case, an empty space may be formed between the polymer resins even when the polymer resins are swelled, and due to the empty space, a liquid may easily pass through portions between the polymer resins, and liquid permeability may be increased.

To sum up, liquid permeability of the liquid provider **3000** may be determined according to the arrangement of polymer resins, and a liquid may be more easily transferred in the case shown in (b) in which liquid permeability is high in comparison to the case shown in (a) in which liquid permeability is low. A larger amount of liquid may be easily transferred to the heat radiator **2000** in the case shown in (b) in which liquid permeability is high, and accordingly, the waste heat dissipation performance may also be improved in the case shown in (b).

2.3.2. Waste Heat Dissipation Performance According to Characteristics of Heat Radiator

2.3.2.1 Waste Heat Dissipation Performance According to Properties of Heat Transferer

FIG. **41** is a view for describing waste heat dissipation performance according to a function of a heat transferer according to an embodiment of the present disclosure.

Referring to FIG. **41**, the heat radiator **2000** may include the heat transferer **2100**, and the heat transferer **2100** may be formed of various materials. Graphs shown in (a) to (c) show temperature changes at the contact surface **1600** in cases in which the feedback device **100** performs the endothermic operation when the heat transferer **2100** is formed of different materials. Specifically, the graphs shown in (a) to (c) show temperature changes at the contact surface **1600** when, as illustrated in FIG. **29**, the heat transferer **2100** is disposed at the lower end of the heat radiator **2000** and comes into contact with the thermoelectric module **1000**. In each of the graphs, the x-axis indicates time, and the y-axis indicates temperature. In the graphs shown in (a) to (c), lines **4101**, **4111**, and **4121** indicate surrounding temperature, and lines **4102**, **4112**, and **4122** indicate the temperature of the contact surface **1600**.

In some embodiments of the present disclosure, in the case of (a), the heat transferer **2100** may be formed of a material having a heat collecting function; in the case of (b), the heat transferer **2100** may be formed of a material having a superior moisture absorbing function that indicates a function of absorbing a liquid; and in the case of (c), the heat transferer **2100** may be formed of a material having a superior waterproof function.

As shown in the graphs of (a) to (c), in the graphs of (a) to (c), respective temperature differences between the lines **4101**, **4111**, **4121** and the lines **4102**, **4112**, and **4122** are not large, and trends of the lines **4102**, **4112**, and **4122** may be similar. From this aspect, it may be confirmed that the function and/or material of the heat transferer **2100** in the case in which the heat transferer **2100** is disposed at the lower end of the heat radiator **2000** has relatively low relevance to the waste heat dissipation performance of the feedback device **100**. This may be due to the fact that a difference in thermal conductivities between general fiber materials such as the materials in the graphs of (a) to (c) is not large.

However, when the heat transferer **2100** is formed of a material having higher heat conduction performance in comparison to general materials, because waste heat from the thermoelectric module **1000** is transferred more easily to the heat dissipator **2200**, the waste heat dissipation performance of the feedback device **100** may be improved.

2.3.2.2. Waste Heat Dissipation Performance According to Properties of Heat Dissipator

FIGS. **42** and **43** are views for describing waste heat dissipation performance according to a function of a heat dissipator according to an embodiment of the present disclosure.

In an embodiment of the present disclosure, the heat radiator **2000** may include the heat dissipator **2200**, and the heat dissipator **2200** may be formed of various materials. Graphs shown in (a) and (b) of FIG. **42** and graphs shown in (a) to (d) of FIG. **43** show temperature changes at the contact surface **1600** in cases in which the feedback device **100** performs the endothermic operation when the heat dissipator **2200** is formed of different materials. Specifically, the graphs shown in FIGS. **42** and **43** show temperature changes at the contact surface **1600** when, as illustrated in FIG. **29**, the heat dissipator **2200** is disposed at the upper end of the heat radiator **2000** and comes into contact with the thermoelectric module **1000**. In each of the graphs, the x-axis indicates time, and the y-axis indicates temperature. In the graphs shown in FIGS. **42** and **43**, lines **4201**, **4211**, **4301**, and **4311** indicate surrounding temperature, and lines **4202**, **4212**, **4302**, **4312**, **4322**, and **4332** indicate the temperature of the contact surface **1600**.

Referring to FIG. **42**, in the case of (a), the heat dissipator **2200** may be formed of a material having air permeability, and in the case of (b), the heat dissipator **2200** may be formed of a material having a waterproof function.

While the line **4202** in the graph shown in (a) indicates that, after the temperature initially drops, the temperature is maintained within a predetermined range, the line **4212** in the graph shown in (b) indicates that, after the temperature initially drops, the temperature continuously rises. That is, it may be confirmed that the waste heat dissipation performance is superior in the graph shown in (a) in comparison to the graph shown in (b). The difference in the waste heat dissipation performance in the graphs shown in (a) and (b) may be due to the heat dissipator **2200** having different functions. Specifically, waste heat may be dissipated in the form of latent heat from the heat dissipator **2200** through a liquid received from the liquid provider **3000**. Here, in the case of (a), due to the air permeability of the heat dissipator **2200**, it is easy for the liquid to be evaporated, and waste heat is actively dissipated. On the other hand, in the case of (b), due to the waterproof function of the heat dissipator **2200**, it is difficult for the liquid to be evaporated, and accordingly, dissipation of waste heat may be difficult.

Referring to FIG. **43**, (a) and (b) are views for describing waste heat dissipation performance according to the endothermic operation of the thermoelectric module **1000** during a relatively small amount of time, and (c) and (d) are views for describing waste heat dissipation performance according to the endothermic operation of the thermoelectric module **1000** during a relatively large amount of time. The heat dissipator **2200** may be formed of a material having a moisture absorbing function and air permeability in all of the cases shown in (a) to (d), but the moisture absorbing function and air permeability of the material of the heat dissipator **2200** in the cases of (b) and (d) may be higher than those of the material of the heat dissipator **2200** in the cases of (a) and (c). For example, the heat dissipator **2200** in the cases of (a) to (d) may be formed of any material of an ethylene vinyl alcohol fiber, a polyethylene vinyl alcohol (EVOH) fiber, a modified cross-section yarn, and a high ventilation material.

In the graphs shown in (a) and (b), the lines **4302** and **4312** indicate that, after the temperature initially drops, the temperature is maintained within a predetermined range. Accordingly, it may be confirmed that differences in the moisture absorbing function and air permeability of the heat dissipator **2200** do not affect the waste heat dissipation performance during a relatively small amount of time.

On the other hand, while the line **4322** in the graph shown in (c) indicates that, after the temperature initially drops, the temperature continuously rises, the line **4332** in the graph shown in (d) indicate that, even after the temperature initially drops, the temperature is maintained within a predetermined range. That is, when the endothermic operation is performed for a long period in the thermoelectric module **1000**, the waste heat dissipation performance may be improved as the moisture absorbing function and air permeability of the heat dissipator **2200** are higher. Accordingly, the longer the period in which the endothermic operation is performed in the thermoelectric module **1000**, the larger the influence of the moisture absorbing function and air permeability of the heat dissipator **2200** on the waste heat dissipation performance of the feedback device **100**.

3. Cold Sensation Providing Performance in Feedback Device

Hereinafter, cold sensation providing performance of the feedback device **100** according to an embodiment of the present disclosure will be described.

3.1. Outline

As described above, when the feedback device **100** operates as a cooling device and the thermoelectric module **1000** performs the endothermic operation, cold sensation is provided to a user while waste heat is generated inside the feedback device **100**. The waste heat may be dissipated to the outside through the heat radiator **2000** of the feedback device **100**.

However, even when the same amount of waste heat is generated and dissipated, cold sensation provided to the user may vary depending on the configuration of the feedback device **100**. For example, when a material that does not dissipate waste heat to the outside for a predetermined period and absorbs waste heat is disposed in the feedback device **100**, due to the material, a surface temperature of the feedback device **100** may not rise even when a larger amount of waste heat is accumulated in the feedback device **100** for a predetermined amount of time, and because of this, cold sensation may be more easily provided to the user.

Hereinafter, a configuration of the feedback device **100** for improving cold sensation providing performance will be described in detail.

3.2. Thermal Buffer Material

3.2.1. Outline

FIG. **44** is a block diagram of a configuration of the feedback device **100** according to another embodiment of the present disclosure.

Referring to FIG. **44**, as described above, the feedback device **100** may include the thermoelectric module **1000**, the heat radiator **2000**, and the liquid provider **3000**. The feedback device **100** may further include a thermal buffer material **4000**. Here, the thermal buffer material **4000** may indicate a material that absorbs a predetermined amount of heat from the outside of the thermal buffer material **4000** and holds the heat.

Because the thermal buffer material **4000** absorbs a predetermined amount of heat and holds the heat, during time in which waste heat to be absorbed into the thermal buffer material **4000** is additionally generated, an extent to which a thermal experience of a user is degraded by the waste heat may be lowered, and the amount of cold heat transferred to the user may be increased.

In an embodiment of the present disclosure, the thermal buffer material **4000** may be provided in various shapes. For example, the thermal buffer material **4000** may be provided as an independent material. As an example, the thermal buffer material **4000** may be disposed as a plurality of independent materials in a partial region of the heat radiator **2000**. As another example, the thermal buffer material **4000** may be provided in the form of a layer. As an example, the thermal buffer material **4000** may be disposed in the form of a layer at one surface of at least one of the thermoelectric module **1000**, the heat radiator **2000**, and the liquid provider **3000**.

The thermal buffer material **4000** may be provided in any shape that may be included in the feedback device **100** in addition to being provided as an independent material or being disposed in the form of a layer. In an embodiment, the thermal buffer material **4000** may be separated from the feedback device **100**. As an example, the thermal buffer material **4000** may be separated from the feedback device **100** and be replaced with another thermal buffer material. As another example, when the thermal buffer material **4000** absorbs heat, the thermal buffer material **4000** may be separated from the feedback device **100** for the heat to be dissipated to the outside of the feedback device **100**.

3.2.2. Properties of Thermal Buffer Material

FIG. **45** is a view for describing a property of a thermal buffer material according to an embodiment of the present disclosure.

Referring to FIG. **45**, the graph shows a temperature change of the thermal buffer material **4000** due to accumulation of thermal energy. The amount of heat applied to the thermal buffer material **4000** may increase from section (a) to section (c).

In an embodiment of the present disclosure, the thermal buffer material **4000** may accumulate a predetermined amount of heat. Here, the thermal buffer material **4000** may not dissipate heat to the outside during a predetermined amount of time in which the predetermined amount of heat is being accumulated.

Specifically, in section (a), heat may be applied to the thermal buffer material **4000**, and the temperature of the thermal buffer material **4000** may rise within section (a). Then, within section (b), the thermal buffer material **4000** may absorb heat, and the temperature of the thermal buffer material may not rise. This is because the thermal buffer material **4000** stores heat being applied within section (b). In an embodiment of the present disclosure, as heat is applied, a phase change may occur in the thermal buffer material **4000**. For example, in section (b), the thermal buffer material **4000** may use the absorbed heat for a phase change. Accordingly, solid and liquid, liquid and gas, or solid and gas may coexist in section (b), and from section (b) to section (c), a phase of the thermal buffer material **4000** may be changed from solid to liquid, liquid to gas, or solid to gas. When the phase of the thermal buffer material **4000** is changed in section (b) in this way, the thermal buffer material **4000** may become a PCM. In section (c), the amount of heat applied to the thermal buffer material **4000** may exceed the amount of heat that the thermal buffer material **4000** is able to hold. In this case, due to heat applied to the thermal buffer material **4000**, the temperature of the thermal buffer material **4000** may rise.

In an embodiment of the present disclosure, the feedback device **100** may use the thermal buffer material **4000** to control a temperature inside the feedback device. Specifically, when a thermoelectric operation is performed and waste heat is generated inside the feedback device, the feedback device **100** may dissipate the waste heat to the outside of the feedback device, and when the amount of waste heat being generated is larger than the amount of waste heat being dissipated, the temperature inside the feedback device may be increased to a first temperature range. Here, the feedback device **100** may use the thermal buffer material **4000** to maintain the temperature inside the feedback device within the first temperature range for a predetermined amount of time so that a temperature rise inside the feedback device is delayed. That is, the feedback device **100** may delay a temperature rise due to waste heat at a contact surface through which the user comes into contact with the feedback device. Specifically, the thermal buffer material **4000** may absorb waste heat and control a surface temperature of the thermal buffer material **4000** to be maintained within a second temperature range. Here, a maximum temperature within the second temperature range may be lower than a maximum temperature within the first temperature range. That is, the surface temperature of the thermal buffer material **4000** may be lower than the temperature inside the feedback device **100**. However, embodiments are not limited thereto, and, depending on an internal structure of the feedback device **10**, the maximum temperature within the second temperature range may be higher than or equal to the maximum temperature within the first temperature range. This indicates that the surface temperature of the thermal buffer material **4000** may be higher than or equal to the temperature inside the feedback device **100**. In an embodiment, the thermal buffer material **4000** may include a PCM, and accordingly, a phase change may occur inside the thermal buffer material **4000** while the surface temperature of the thermal buffer material **4000** is being maintained within the second temperature range.

As described above, when the thermal buffer material **4000** includes a PCM, the thermal buffer material **4000** may hold a larger amount of heat due to a phase change. Hereinafter, the PCM will be described in detail.

The PCM is a material having high heat of fusion and may be melted or hardened at specific temperature, thereby storing or releasing a large amount of thermal energy. In an embodiment, the PCM may store or dissipate heat through a chemical bond. As an example, in a case in which the PCM is a material whose phase is changed from solid to liquid, when heat is applied to the PCM in a solid state, the temperature of the PCM is increased, and when the temperature of the PCM reaches a melting point or a phase change temperature of the PCM, the PCM continues to absorb heat, but the temperature of the PCM is not increased. Here, the phase of the PCM is changed from solid to liquid. Then, when heat is not applied to the PCM, the PCM dissipates the heat accumulated therein to the outside, and accordingly, the phase of the PCM may be restored to solid from liquid. In this way, although the temperature of the PCM increases from an initial temperature to a phase change temperature, after the phase change temperature is reached, the temperature of the PCM is not increased until a phase change is completed. Each PCM may have a unique phase change temperature, and when the thermal buffer material **4000** is formed of the PCM, the phase change temperature of the PCM may be included within a range of a temperature change inside the feedback device **100**. When the phase change temperature of the PCM is not included within the range of a temperature change inside the feedback device **100**, a phase change does not occur in the PCM even when waste heat is accumulated inside the feedback device **100**. Accordingly, the temperature of the PCM is continuously increased, and the PCM is unable to serve as the thermal buffer material **4000**. For example, the phase change temperature of the PCM may be within 5° C. to 60° C. or within 20° C. to 40° C.

In an embodiment of the present disclosure, the PCM used in the thermal buffer material **4000** may be formed of various materials. For example, the PCM may include a hydrated inorganic salt such as hydrated calcium chloride, lithium nitrogen oxide, and Glauber's salt, a polyhydric alcohol such as dimethyl propanediol (DMP), hexamethyl propanediol (HMP), xylitol, and erhthritol, and linear chain hydrocarbon such as polyethylene terephthalate (PET)-polyethylene glycol (PEG) copolymer, PEG, polytetramethyl glycol (PTMG), and paraffin.

In an embodiment of the present disclosure, the PCM used in the thermal buffer material **4000** may be implemented in various forms. For example, the PCM may be included in a microcapsule, filled in fabric, or coated.

3.2.3. Applications of Thermal Buffer Material According to Various Embodiments

3.2.3.1. First Embodiment

FIG. **46** is a view illustrating a structure of the feedback device to which the thermal buffer material is applied according to an embodiment of the present disclosure.

Referring to FIG. **46**, as in the first embodiment illustrated in FIG. **29**, the thermoelectric module **1000** and the heat radiator **2000** may be stacked in that order in the feedback device **100**, and the liquid provider **3000** may be disposed inside the heat radiator **2000**. The heat radiator **2000** may include the heat transferer **2100** and the heat dissipator **2200**. The waste heat transfer path may be formed with the thermoelectric module **1000**, the heat transferer **2100**, the liquid provider **3000**, and the heat dissipator **2200**.

In an embodiment of the present disclosure, the thermal buffer material **4000** may be formed as an independent material and disposed in the heat dissipator **2200**. For example, the thermal buffer material **4000** may be formed of xylitol and/or erithritol among PCMs. Here, xylitol and erithritol may be components that reacts with moisture as sugar alcohol, causes an endothermic reaction, and takes heat away from the surroundings, thereby causing a user to feel coldness.

As a more specific example, when the thermal buffer material **4000** formed of xylitol and/or erithritol is disposed in the heat dissipator **2200**, the thermal buffer material **4000** may react with a liquid transferred from the liquid provider **3000**, cause an endothermic reaction, and absorb waste heat around the thermal buffer material **4000**. In this case, because the amount of waste heat in the feedback device **100** is reduced due to the thermal buffer material **4000** for a predetermined amount of time, cold sensation providing performance of the feedback device **100** may be improved.

When a user comes into contact with the heat dissipator **2200**, the thermal buffer material **4000** may absorb heat from the user. Accordingly, the user may more strongly feel coldness due to the thermal buffer material **4000**.

3.2.3.2. Second Embodiment

FIG. **47** is a view illustrating a structure of the feedback device to which the thermal buffer material is applied according to another embodiment of the present disclosure.

Referring to FIG. **47**, the thermoelectric module **1000** and the heat radiator **2000** may be stacked in that order in the feedback device **100**, and the liquid provider **3000** may be disposed inside the heat radiator **2000**. Here, the thermal buffer material **4000** may be disposed between the heat radiator **2000** and the thermoelectric module **1000**. Here, the thermal buffer material **4000** may be implemented in the form of a layer. The heat radiator **2000** may include the heat transferer **2100** and the heat dissipator **2200**. The waste heat transfer path may be formed with the thermoelectric module **1000**, the thermal buffer material **4000**, the heat transferer **2100**, the liquid provider **3000**, and the heat dissipator **2200**.

In an embodiment of the present disclosure, because the thermal buffer material **4000** is disposed between the thermoelectric module **1000** and the heat transferer **2100**, the amount of waste heat accumulated inside the feedback device **100** is reduced for a predetermined amount of time, and transfer of waste heat from the thermoelectric module **1000** to the heat transferer **2100** may be delayed. As a specific example, when the thermoelectric module **1000** performs the endothermic reaction, waste heat may be generated in the thermoelectric module **1000**. When the generated waste heat is transferred to the thermal buffer material **4000**, although the temperature of the thermal buffer material **4000** rises to a phase change temperature due to the waste heat, the temperature of the thermal buffer material **4000** is maintained at the phase change temperature until a phase change of the thermal buffer material **4000** is completed.

Here, because the thermal buffer material **4000** absorbs waste heat while the temperature of the thermal buffer material **4000** is maintained at the phase change temperature, waste heat may not be accumulated inside the feedback device **100**, and waste heat having a higher temperature than the phase change temperature may not be transferred from the thermal buffer material **4000** to the heat transferer **2100**. Then, when the phase change of the thermal buffer material **4000** is completed, waste heat having a higher temperature than the phase change temperature may be further accumulated inside the feedback device **100**, and the waste heat may be transferred to the heat transferer **2100**. In this way, while the temperature of the thermal buffer material **4000** is maintained at the phase change temperature, the amount of waste heat inside the feedback device **100** may be decreased in comparison to a case in which the thermal buffer material **4000** is not included. Because an influence of the waste heat on the user's thermal experience decreases while the temperature of the thermal buffer material **4000** is maintained at the phase change temperature, the cold sensation providing performance of the feedback device **100** may be improved.

3.2.3.3. Third Embodiment

FIG. **48** is a view illustrating a structure of the feedback device to which the thermal buffer material is applied according to still another embodiment of the present disclosure.

Referring to FIG. **48**, the thermoelectric module **1000** and the heat radiator **2000** may be stacked in that order in the feedback device **100**, and the liquid provider **3000** may be disposed inside the heat radiator **2000**. Here, the thermal buffer material **4000** may be disposed below the thermoelectric module **1000**. Here, the thermal buffer material **4000** may be implemented in the form of a layer. The heat radiator **2000** may include the heat transferer **2100** and the heat dissipator **2200**. The waste heat transfer path may be formed with the thermoelectric module **1000**, the heat transferer **2100**, the liquid provider **3000**, and the heat dissipator **2200**.

In an embodiment of the present disclosure, the phase change temperature of the thermal buffer material **4000** may be higher than a temperature of cold heat generated from the thermoelectric module **1000**. Accordingly, the phase change of the thermal buffer material **4000** may not occur due to the cold heat, and the thermal buffer material **4000** may not affect providing cold sensation to a user.

As the thermoelectric module **1000** continuously performs the endothermic operation, cold heat may be transferred to the user while waste heat is accumulated inside the feedback device **100**. When the amount of waste heat being generated is larger than the amount of waste heat being dissipated, waste heat may also be accumulated in locations other than the waste heat transfer path. Because of this, waste heat may also be transferred to the user in addition to the cold heat. However, because the thermal buffer material **4000** is disposed at the lower end of the thermoelectric module **1000**, the thermal buffer material **4000** may absorb and store the accumulated waste heat. After the temperature of the thermal buffer material **4000** reaches the phase change temperature, the temperature of the thermal buffer material **4000** may be maintained at a predetermined temperature. Accordingly, the thermal buffer material **4000** blocks waste heat from being transferred to the user, and thus the cold sensation providing performance of the feedback device **100** may be improved.

3.2.3.4. Fourth Embodiment

FIG. **49** is a view illustrating a structure of the feedback device to which the thermal buffer material is applied according to yet another embodiment of the present disclosure.

Referring to FIG. **49**, the thermoelectric module **1000** and the heat radiator **2000** may be stacked in that order in the feedback device **100**, and the liquid provider **3000** may be disposed inside the heat radiator **2000**. Here, the thermal buffer material **4000** may be disposed at a lower end of the liquid provider **3000** inside the heat radiator **2000**. Here, the thermal buffer material **4000** may be implemented in the form of a layer. The heat radiator **2000** may include the heat transferer **2100** and the heat dissipator **2200**. The waste heat transfer path may be formed with the thermoelectric module **1000**, the heat transferer **2100**, the thermal buffer material **4000**, the liquid provider **3000**, and the heat dissipator **2200**.

In an embodiment of the present disclosure, because the thermal buffer material **4000** is disposed at the lower end of the liquid provider **3000**, the amount of waste heat being accumulated inside the feedback device **100** may be reduced for a predetermined amount of time, and transfer of waste heat from the heat transferer **2100** to the liquid provider **3000** may be delayed. As a specific example, when the waste heat generated in the thermoelectric module **1000** is transferred to the thermal buffer material **4000** through the heat transferer **2100**, the temperature of the thermal buffer material **4000** may be increased to a phase change temperature due to the waste heat, but the temperature of the thermal buffer material **4000** may be maintained at the phase change structure until a phase change of the thermal buffer material **4000** is completed. Here, because the thermal buffer material **4000** absorbs waste heat while the temperature of the thermal buffer material **4000** is maintained at the phase change temperature, the amount of waste heat being accumulated inside the feedback device **100** may be reduced, and waste heat having a higher temperature than the phase change temperature may not be transferred from the thermal buffer material **4000** to the liquid provider **3000**. Because of this, an influence of the waste heat on the user's thermal experience decreases while the temperature of the thermal buffer material **4000** is maintained at the phase change temperature, and thus the cold sensation providing performance of the feedback device **100** may be improved.

3.2.3.5. Fifth Embodiment

FIG. **50** is view illustrating a structure of the feedback device to which the thermal buffer material is applied according to yet another embodiment of the present disclosure.

Referring to FIG. **50**, the thermoelectric module **1000** and the heat radiator **2000** may be stacked in that order in the feedback device **100**, and the liquid providers **3000**-*a* and **3000**-*b* may be disposed at both side surfaces of the heat radiator **2000**. The supporter **5000** may be disposed at side surfaces of the thermoelectric module **1000**, and the liquid providers **3000**-*a* and **3000**-*b* may be disposed at an upper end of the supporter **5000**. The thermal buffer material **4000** may be disposed in the form of a layer between the thermoelectric module **1000** and the heat radiator **2000**. Accordingly, the waste heat transfer path may be formed with the thermoelectric module **1000**, the thermal buffer material **4000**, and the heat radiator **2000**. As described with reference to FIG. **30**, because the liquid provides **3000**-*a* and **3000**-*b* are excluded from the waste heat transfer path, the waste heat transfer path may be shortened, and thus the waste heat dissipation performance may be improved.

Because the thermal buffer material **4000** is disposed between the thermoelectric module **1000** and the heat radiator **2000**, and the temperature of the thermal buffer material **4000** is not increased in a phase change temperature section, the amount of waste heat being accumulated inside the feedback device **100** may be reduced while the temperature of the thermal buffer material **4000** is maintained at the phase change temperature, and transfer of waste heat from the thermoelectric module **1000** to the heat radiator **2000** may be delayed. In this way, because an influence of the waste heat on the user's thermal experience decreases while the temperature of the thermal buffer material **4000** is maintained at the phase change temperature, the cold sensation providing performance of the feedback device **100** may be improved.

FIG. **51** is a view for describing cold sensation providing performance that is improved by the thermal buffer material according to an embodiment of the present disclosure.

Referring to FIG. **51**, the graph of FIG. **51** shows temperature of heat being provided from the feedback device **100** to the user. The x-axis of the graph indicates time, and the y-axis thereof indicates temperature. A line **5101** shows the temperature of the contact surface **1600** when the thermal buffer material **4000** is not included in the feedback device **100**, and a line **5102** shows the temperature of the contact surface **1600** when the thermal buffer material **4000** is included in the feedback device **100**.

In the graph of FIG. **51**, the line **5102** shows a lower minimum temperature than that of the line **5101**, and the amount of time taken for the line **5102** to reach a saturation temperature may be larger than the amount of time taken for the line **5101** to reach a saturation temperature. This may be due to the reduction in the amount of waste heat being accumulated inside the feedback device **100** for a predetermined amount of time due to the thermal buffer material **4000** and the delay in the transfer of waste heat from the thermoelectric module **1000** to another element as described above in the second embodiment to the fifth embodiment. Consequently, as shown in the graph of FIG. **51**, when the thermal buffer material **4000** is included in the feedback device **100**, the user may more steadily receive coldness at a lower temperature.

FIG. **52** is a view for describing cold sensation providing performance that is improved by the thermal buffer material according to another embodiment of the present disclosure.

Referring to FIG. **52**, (a) is a graph showing density of power generated with time, and (b) is a graph showing a level of voltage of power being generated with time.

In the graph of (a), the x-axis indicates time, and the y-axis indicates power density ($\mu W/cm^2$) indicating a power generation amount per unit area generated in the feedback device **100**. In the graph of (b), the x-axis indicates time, and the y-axis indicates a level of voltage (mV) of power being generated in the feedback device **100**.

In the graphs of (a) and (b), a line **5201** shows a power density when the thermal buffer material **4000** is not included in the feedback device **100**, a line **5211** shows a voltage when the thermal buffer material **4000** is not included in the feedback device **100**, a line **5202** shows a power density when the thermal buffer material **4000** is included in the feedback device **100**, and a line **5212** shows a voltage when the thermal buffer material **4000** is not included in the feedback device **100**.

As shown in the graphs of (a) and (b), the power density or voltage, that is, power generation efficiency, may be higher in the case in which the thermal buffer material **4000** is included in the feedback device **100** in comparison to when the thermal buffer material **4000** is not included in the feedback device **100**. This signifies that a temperature difference in the thermoelectric module **1000** increases when the thermal buffer material **4000** is included in the feedback device **100**. The increase in the temperature difference in the thermoelectric module **1000** may indicate an improvement in the waste heat dissipation performance in the feedback device **100**. The improvement in the waste heat dissipation performance may, as a result, indicate an improvement in the cold sensation providing performance. Consequently, when the thermal buffer material **4000** is included in the feedback device **100**, performance of providing cold sensation to the user may be improved, and power generation efficiency may also be improved.

4. Method of Improving the User'S Perception Performance of Feedback Device

Hereinafter, a method of improving the user's perception performance of the feedback device **100** according to an embodiment of the present disclosure will be described.

4.1. Outline

As described above, the feedback device **100** may perform an endothermic operation and provide cold feedback to the user. Accordingly, the user may perceive cold sensation from the feedback device **100**.

The feedback device **100** may control whether cold feedback is provided and adjust an intensity of cold feedback. Because the endothermic operation is performed in the feedback device **100**, waste heat may be accumulated in the feedback device **100**, and the cold feedback provided to the user may be affected by the accumulated feedback. Due to such factors, the user may receive cold feedback of various intensities at various times, and accordingly, the extent of cold sensation perceived by the user may vary.

More specifically, FIG. **53** is a view illustrating a graph related to a temperature of heat provided to a user from the feedback device according to an embodiment of the present disclosure. In the graph of FIG. **53**, the x-axis indicates time, the y-axis indicates temperature, and the line **5301** indicates the temperature of the contact surface **1600** of the thermoelectric module **1000** with time. In FIG. **53**, as a predetermined voltage at a single level is applied to the thermoelectric module **1000**, the thermoelectric module **1000** may perform the endothermic operation, and as cold heat according to the endothermic operation is transferred to the contact surface **1600**, the temperature of the contact surface **1600** may drop. However, as the thermoelectric module **1000** performs the endothermic operation, waste heat may be accumulated in the feedback device **100**, and due to the influence of the waste heat, after reaching a minimum temperature, the temperature of the contact surface **1600** may rise and be maintained within the predetermined temperature section **5322**.

In some embodiments of the present disclosure, cold heat transfer performance, which indicates performance in which cold heat is transferred, may be may include three indicators. The first indicator of the cold heat transfer performance is the amount of time taken to reach a minimum temperature that indicates a speed at which the minimum temperature is reached. In the example of FIG. **53**, the amount of time taken to reach the minimum temperature may be the section **5311**. When the temperature of the contact surface **1600** reaches the minimum temperature faster and the section **5311** is shortened, the cold heat transfer performance of the feedback device **100** may be improved. The second indicator of the cold heat transfer performance is a duration time that indicates how long the temperature of the contact surface lasts. This is because, when a large amount of waste heat is accumulated in the feedback device **100**, the temperature of the contact surface **1600** rises instead of being maintained at a specific temperature due to the accumulated waste heat, and cold heat is unable to be normally transferred to the user due to the feedback device **100** becoming hot.

In the example of FIG. **53**, the duration time may be time in which the temperature of the contact surface **1600** is maintained within the temperature section **5322**. When the temperature of the contact surface **1600** is maintained within the temperature section **5322** for a larger amount of time, the cold heat transfer performance of the feedback device **100** may be improved. The third indicator of the cold heat transfer performance is a lasting temperature that indicates the temperature of the contact surface **1600** during the duration time. As described above, although the temperature of the contact surface **1600** is unable to be maintained at the minimum temperature due to the waste heat, because the waste heat is dissipated from the feedback device **100**, the temperature of the contact surface **1600** may be maintained at a temperature higher than the minimum temperature, and the higher temperature may be the lasting temperature. Here, when a temperature value of the lasting temperature is increased, cold heat is unable to be normally transferred to the user due to the feedback device **100** becoming hot. In the example of FIG. **53**, the lasting temperature may be the temperature section **5322**. When the temperature in the temperature section **5322** is decreased, the cold heat transfer performance of the feedback device **100** may be improved.

As the indicators of the cold heat transfer performance are improved, the extent to which the user perceives cold feeling may be mostly improved. The improvements in the indicators of the cold heat transfer performance indicate that the feedback device **100** is not greatly affected by the waste heat. Because of this, the user receives cold feedback that is not greatly affected by the waste heat. In this way, the extent to which the user perceives cold sensation may be improved.

In an embodiment of the present disclosure, when a voltage value applied to the thermoelectric module **1000** is changed or a plurality of voltages having different voltage values are applied to the thermoelectric module **1000**, the minimum temperature of the contact surface **1600** and the temperature section **5322** in which the temperature of the contact surface **1600** is maintained may be changed. Even when a time point at which a voltage is applied to the thermoelectric module **1000** is changed, the minimum temperature of the contact surface **1600** and the temperature section **5322** in which the temperature of the contact surface **1600** is maintained may be changed. As a result, cold heat provided to the user is changed according to a level of a voltage applied to the thermoelectric module **1000** and a time point at which the voltage is applied, and the amount of time taken to reach the minimum temperature, the duration time, and the lasting temperature, which are indicators of the cold heat transfer performance, are also changed such that the extent to which the user perceives cold sensation due to cold feedback provided from the feedback device **100** is also changed.

Hereinafter, a method of improving cold feeling perception of the user in a situation in which cold heat provided to the user changes due to various conditions will be described.

4.2. Method of Improving the User'S Perception Performance by Applying a Plurality of Voltages

FIG. **54** is an operational flowchart illustrating a method of improving the user's perception performance by applying a plurality of voltages according to an embodiment of the present disclosure.

Referring to FIG. **54**, when the feedback device **100** provides cold feedback, to improve a user's cold sensation perception performance(of cold feeling perception performance), the feedback device **100** may determine a voltage value of a voltage to be applied to the thermoelectric module **1000** and a time point at which the voltage is to be applied. When the feedback device **100** determines to apply voltage values at two different voltage levels at two different time points, the feedback device **100** may apply a first voltage value at a first time point (**5410**). Also, the feedback device **100** may apply a second voltage value at a second time point (**5420**). As Steps **5410** and **5420** are performed, the user's cold sensation perception performance may be improved. Hereinafter, Steps **5410** and **5420** will be described in more detail. Although an embodiment in which voltage values at two different voltage levels are applied at two different time points is described with reference to FIG. **54**, embodiments are not limited thereto, and the method of improving the user's perception performance of the feedback device **100** according to an embodiment of the present disclosure may also be applied to a case in which voltage values at three or more different levels are applied at various time points.

FIG. **55** is a view for describing cold heat transfer performance of the feedback device by adjusting a voltage according to an embodiment of the present disclosure.

Referring to FIG. **55**, the x-axis of the graph indicates time, the y-axis thereof indicates temperature, and, as in FIG. **53**, the line **5301** indicates the temperature of the contact surface **1600** when a voltage Va, which is a voltage at a single level, is applied. Here, the line **5301** may be shown in different forms according to Step **5410** and Step **5420**.

Specifically, in some embodiments of the present disclosure, in Step **5410**, the feedback device **100** may apply a first voltage V**1** at a first time point t**1**. In an embodiment, when the first voltage V**1** is equal to the voltage Va, the temperature of the contact surface **1600** may be represented by a line equal to the line **5301**.

However, in an embodiment, the first voltage V**1** may be at a lower level than the voltage Va. In this case, the thermoelectric module **1000** may output thermal feedback at a lower intensity in comparison to when the voltage Va is applied, and accordingly, a wanted temperature at the contact surface **1600** when the first voltage V**1** is applied may be higher than a wanted temperature at the contact surface **1600** when the voltage Va is applied. Consequently, in the section **5311**, the temperature of the contact surface **1600** may be represented as being higher than the line **5301**.

On the other hand, because the thermal feedback at the lower intensity in comparison to when the voltage Va is applied is output, when the first voltage V**1** is applied, a smaller amount of waste heat may be generated in comparison to when the voltage Va is applied. Accordingly, an amount of time taken to reach a minimum temperature that indicates the amount of time for the temperature of the contact surface **1600** to reach the wanted temperature at the contact surface **1600** when the first voltage V**1** is applied may be shortened in comparison to when the voltage Va is applied. However, according to circumstances, the amount of time taken for the temperature of the contact surface **1600** to reach the wanted temperature at the contact surface **1600** when the first voltage V**1** is applied may be relatively large depending on a level of the first voltage V**1**. This may be due to the fact that, despite a small amount of waste heat being generated, a speed at which a temperature initially drops is slow in some of the thermoelectric pair arrays **1240**. That is, a speed at which a temperature initially drops may be related to characteristics of the thermoelectric pair array **1240** in addition to the amount of waste heat being generated.

When the first voltage V**1** is applied in the section **5311** while it is assumed that the voltage Va is applied in the section **5312**, because the amount of waste heat generated in the section **5311** is smaller in comparison to when the voltage Va is applied in the section **5311**, the duration time in the section **5312** may be longer. Because the small amount of waste heat is generated, the lasting temperature in the section **5312** may be lowered.

In another embodiment, the first voltage V**1** may be at a higher level than the voltage Va. In this case, the thermoelectric module **1000** may output thermal feedback at a higher intensity in comparison to when the voltage Va is applied, and accordingly, the wanted temperature at the contact surface **1600** when the first voltage V**1** is applied may be lower than the wanted temperature at the contact surface **1600** when the voltage Va is applied. Consequently, in the section **5311**, the temperature of the contact surface **1600** may be represented as being lower than the line **5301**.

In some of the thermoelectric pair arrays **1240**, the amount of time taken to reach a wanted temperature may be smaller as a level of a voltage being applied thereto is higher. In this case, the amount of time taken to reach a minimum temperature when the first voltage V**1** is applied may be smaller in comparison to when the voltage Va is applied.

On the other hand, because the thermal feedback at the higher intensity in comparison to when the voltage Va is applied is output, a larger amount of waste heat in comparison to when the voltage Va is applied may be generated. In this case, when the amount of waste heat is accumulated by a threshold value or more, the waste heat may affect the temperature of the contact surface **1600**, and accordingly, the amount of time taken to reach the minimum temperature when the first voltage V**1** is applied may be larger in comparison to when the voltage Va is applied.

When the first voltage V**1** is applied in the section **5311** while it is assumed that the voltage Va is applied in the section **5312**, because the amount of waste heat generated in the section **5311** is larger in comparison to when the voltage Va is applied in the section **5311**, the duration time in the section **5312** may be shortened. Because the large amount of waste heat is generated, the lasting temperature in the section **5312** may be increased. This may vary according to the amount of waste heat being generated, and when a difference between the amount of waste heat when the voltage Va is applied in the section **5312** and the amount of waste heat when the first voltage V**1** is applied in the section **5312** is not large, the duration time and the lasting temperature may be similar with those in the case in which the voltage Va is applied in the section **5312**.

In some embodiments of the present disclosure, in Step **5420**, the feedback device **100** may apply a second voltage V**2** at a second time point t**2**. In an embodiment, when the first voltage V**1** and the second voltage V**2** are equal to the voltage Va, the temperature of the contact surface **1600** may be represented by a line equal to the line **5301**.

However, in an embodiment, the second voltage V**2** may be at a lower level than the voltage Va. In this case, the thermoelectric module **1000** may output thermal feedback at a lower intensity in comparison to when the voltage Va is applied, and accordingly, a wanted temperature at the contact surface **1600** when the second voltage V**2** is applied may be higher than a wanted temperature at the contact surface **1600** when the voltage Va is applied. Consequently, in the section **5312**, the lasting temperature when the second voltage V**2** is applied may be higher in comparison to when the voltage Va is applied.

However, because the thermal feedback at the lower intensity in comparison to when the voltage Va is applied is output, when the second voltage V**2** is applied, a smaller amount of waste heat may be generated in comparison to when the voltage Va is applied. When the lasting temperature in the case in which the voltage Va is applied is shown to be high due to the waste heat, a small amount of waste heat may be generated when the second voltage V**2** is applied, and the lasting temperature may not be greatly affected by the waste heat when the second voltage V**2** is applied. Because of this, although a wanted temperature at the contact surface **1600** when the second voltage V**2** is applied is higher than a wanted temperature at the contact surface **1600** when the voltage Va is applied, a lasting temperature when the second voltage V**2** is applied in the section **5312** may be lower in comparison to when the voltage Va is applied in the section **5312** according to circumstances.

Because the smaller amount of waste heat is generated when the second voltage V**2** is applied in comparison to when the voltage Va is applied, a duration time when the second voltage V**2** is applied may be longer in comparison to when the voltage Va is applied.

In another embodiment, the second voltage V**2** may be at a higher level than the voltage Va. In this case, the thermoelectric module **1000** may output thermal feedback at a higher intensity in comparison to when the voltage Va is applied, and accordingly, the wanted temperature at the contact surface **1600** when the second voltage V**2** is applied may be lower than the wanted temperature at the contact surface **1600** when the voltage Va is applied. Consequently, in the section **5312**, the lasting temperature when the second voltage V**2** is applied may be lower in comparison to when the voltage Va is applied.

However, because the thermal feedback at the higher intensity in comparison to when the voltage Va is applied is output, when the second voltage V**2** is applied, a larger amount of waste heat may be generated in comparison to when the voltage Va is applied. According to circumstances, the lasting temperature may be affected by the waste heat, and in this case, the lasting temperature when the second voltage V**2** is applied in the section **5312** may be higher in comparison to when the voltage Va is applied. Because a larger amount of waste heat is generated when the second voltage V**2** is applied in comparison to when the voltage Va is applied, the duration time when the second voltage V**2** is applied may be shorter in comparison to when the voltage Va is applied. According to the amount of waste heat being generated or characteristics of the feedback device **100**, the duration time may not be greatly affected by the waste heat. In this case, the duration time when the second voltage V**2** is applied may be similar to that when the voltage Va is applied.

Accordingly, the feedback device **100** may determine a voltage to be applied to the thermoelectric module **1000** so that the amount of time taken to reach a minimum temperature is reduced, the duration time is increased, and the lasting temperature is lowered and, through Step **5410** and Step **5420**, may apply the determined voltage to improve the cold heat transfer performance.

FIG. **56** is a view for describing cold heat transfer performance of the feedback device by adjusting a time point at which a voltage is applied according to an embodiment of the present disclosure.

Referring to FIG. **56**, the x-axis of the graph indicates time, the y-axis thereof indicates temperature, and, as in FIG. **53**, the line **5301** indicates the temperature of the contact surface **1600** when the voltage Va, which is a voltage at a single level, is applied. Here, the line **5301** may be shown in different forms according to Step **5410** and Step **5420**.

Specifically, in some embodiments of the present disclosure, in Step **5410**, the feedback device **100** may apply the first voltage V**1** at the first time point t**1**. In an embodiment, when the first voltage V**1** is equal to the voltage Va, the temperature of the contact surface **1600** may be represented by a line equal to the line **5301**.

In an embodiment, in Step **5420**, the feedback device **100** may apply the second voltage V**2** at the second time point t**2**. In an embodiment, when the first voltage V**1** and the second voltage V**2** are equal to the voltage Va, the temperature of the contact surface **1600** may be represented by a line equal to the line **5301**.

However, in an embodiment, the first voltage V**1** may be at a higher level than the second voltage V**2**, and the second time point t**2** in FIG. **56** may be earlier than a time point at which the temperature of the contact surface **1600** reaches a minimum temperature in FIG. **53**. In this case, the second time point t**2** in FIG. **56** may be a time point before the temperature of the contact surface **1600** reaches the minimum temperature by the first voltage V**1**. Accordingly, the temperature of the contact surface **1600** may not reach the minimum temperature, and as a result, the user may not receive intended cold heat.

On the other hand, in another embodiment, the first voltage V**1** may be at a higher level than the second voltage V**2**, and the second time point t**2** in FIG. **56** may be later than the time point at which the temperature of the contact surface **1600** reaches the minimum temperature in FIG. **53**. In this case, the second time point t**2** in FIG. **56** may be a time point after the temperature of the contact surface **1600** reaches the minimum temperature by the first voltage V**1**, and the temperature of the contact surface **1600** may be maintained at the minimum temperature. However, because the first voltage V**1** is continuously applied between the first time point t**1** and the second time point t**2**, a larger amount of waste heat may be generated in comparison to when the second voltage V**2** is applied. Because of this, the temperature of the contact surface **1600** may rise instead of being maintained at the minimum temperature, and the generated waste heat may also affect the temperature of the contact surface **1600** after the second time point t**2**. According to circumstances, due to the waste heat, the duration time may be shortened, and the lasting temperature may be increased. According to the amount of waste heat being generated or characteristics of the feedback device **100**, the duration time may not be greatly affected by the waste heat. In this case, even when the second time point t**2** in FIG. **56** is later than the time point at which the temperature of the contact surface **1600** reaches the minimum temperature in FIG. **53**, the temperature of the contact surface **1600** may be maintained at the minimum temperature, and the influence on the duration time and the lasting temperature may be small.

Consequently, the feedback device **100** may determine a time point at which a voltage is to be applied so that the temperature of the contact surface **1600** reaches the minimum temperature and the duration time and the lasting temperature are improved and, through Step **5410** and Step **5420**, may apply a voltage at the determined time point to improve the cold heat transfer performance.

FIG. **57** is a view for describing cold heat transfer performance of the feedback device in response to applying a plurality of voltages according to an embodiment of the present disclosure.

Referring to FIG. **57**, Although the cold heat transfer performance of the feedback device **100** has been described on the basis of an embodiment in which voltages at two different levels are applied in the examples of FIGS. **55** and **56**, an embodiment in which voltages at three or more different levels are applied as illustrated in FIG. **57** may also be applied to the present disclosure.

In FIG. **57**, the x-axis of the graph indicates time, the y-axis thereof indicates temperature, and a line **5701** indicates temperature of the contact surface **1600** when a first voltage V**1** to a fifth voltage V**5** are applied.

In an embodiment of the present disclosure, when the feedback device **100** provides cold feedback, the feedback device **100** may determine levels of a plurality voltages to be applied to the thermoelectric module **1000** and time points at which the plurality of voltages are to be applied so that the user's cold sensation perception performance is improved.

In the example of FIG. **57**, the first voltage V**1** to the fifth voltage V**5** may have sequentially higher voltage values in that order. That is, the first voltage V**1** may be set to have the lowest voltage value, and the fifth voltage V**5** may be set to have the highest voltage value. The first voltage V**1** to the fifth voltage V**5** may be set to be applied at a first time point t**1** to a fifth time point to, respectively. In an embodiment, between the first time point t**1** and a second time point t**2**, the temperature of the contact surface **1600** may reach a minimum temperature and then gradually rise due to waste heat. When the second voltage V**2** is applied between the second time point t**2** and a third time point to, the temperature of the contact surface **1600** may temporarily drop and then rise. Also, between the third time point to and a fourth time point to and between the fourth time point to and the fifth time point to, when a third voltage VA or a fourth voltage VA is applied, the temperature of the contact surface **1600** may temporarily drop and then rise. After the fifth time point to, when the fifth voltage V**5** is applied, the temperature of the contact surface **1600** may temporarily drop and then rise, but in this case, the temperature of the contact surface **1600** may be maintained at a specific temperature.

In this way, according to circumstances, in the case in which voltages at sequentially higher levels are applied, because a wanted temperature of the contact surface **1600** is decreased when a voltage at a high level is applied, the temperature of the contact surface **1600** may be gradually decreased or maintained. Because the temperature of the contact surface **1600** temporarily drops at the second time point t**2** to the fifth time point to, the user may feel strong cold sensation at the corresponding time points.

Accordingly, the feedback device **100** may determine a plurality of voltages and time points at which the plurality of voltages are to be applied corresponding to characteristics of the feedback device **100** and apply the plurality of voltages at the plurality of time points, thereby improving the cold heat transfer performance. Although the embodiment in which voltage values become sequentially higher has been described with reference to FIG. **57**, embodiments are not limited thereto, and levels of the plurality of voltages to be applied to the thermoelectric module **1000** may be set to various values.

4.3. Method of Improving User'S Perception by Controlling Thermoelectric Operation

As described above, in an embodiment, when the feedback device **100** performs the endothermic operation, after reaching the minimum temperature, the temperature of the contact surface **1600** may slightly rise due to waste heat and reach a lasting temperature, which is a temperature within a predetermined temperature range. The user may receive cold sensation from such a temperature change of the contact surface **1600**.

However, even when cold heat is continuously transferred from the feedback device **100**, the user may not feel coldness at a certain level. Particularly, in a section in which the feedback device **100** maintains the lasting temperature, the user's cold sensation perception may be degraded, and according to circumstances, the user may not feel coldness. This is due to a characteristic of sensory organs of the human body in that, when stimulation at a specific intensity is continued, the sensory organs of the human body are unable to feel stimulation at the corresponding intensity and may perceive a change in stimulation only when stimulations of a predetermined proportion or more with respect to the stimulation at the specific intensity are applied. This may be described also using the Weber's law.

Hereinafter, a method of improving the user's cold sensation perception by the feedback device **100** despite the characteristic of sensory organs of the human body will be described.

FIG. **58** is an operational flowchart illustrating a method of improving the user's perception performance by controlling a thermoelectric operation according to an embodiment of the present disclosure.

Referring to FIG. **58**, the feedback device **100** may improve the user's cold sensation perception by performing a thermoelectric operation and stopping the thermoelectric operation.

Specifically, the feedback device **100** may determine a first period in which a thermoelectric operation is performed and a second period in which the thermoelectric operation is stopped. The feedback device **100** may perform a thermoelectric operation during the first period (**5810**). The feedback device **100** may stop the thermoelectric operation during the second period (**5820**). The feedback device may repeatedly perform Step **5810** and Step **5820** while cold sensation is provided to the user, and accordingly, the user's perception performance may be improved. Hereinafter, Step **5810** and Step **5820** will be described in more detail.

FIG. **59** is a view for describing periods for controlling a thermoelectric operation according to an embodiment of the present disclosure.

Referring to FIG. **59**, the x-axis of the graph indicates time, and the y-axis thereof indicates voltage. The feedback device **100** may apply and not apply a voltage at a specific level to control a thermoelectric operation. Here, the thermoelectric operation may include an exothermic operation and an endothermic operation. For example, when the feedback device **100** applies a first voltage having a specific voltage value during a first period T**1**, the thermoelectric module **1000** may output cold feedback according to the first voltage, and when the feedback device **100** stops the application of the first voltage during a second period T**2**, the thermoelectric module **1000** may not output the cold feedback. The feedback device **100** may repeat the application of the first voltage and the stopping of the application of the first voltage according to the first period T**1** and the second period T**2** in accordance with an overall period T so that the extent to which the user perceives cold sensation is improved. Although controlling a thermoelectric operation when the same voltage is applied has been described with reference to FIG. **59**, embodiments are not limited thereto, and a case in which a plurality of voltages having different voltage values are applied may also be applied to the method of improving the user's perception performance by controlling a thermoelectric operation according to an embodiment of the present disclosure.

FIG. **60** is a view for describing a method of improving the user's perception performance by controlling a thermoelectric operation according to an embodiment of the present disclosure.

Referring to FIG. **60**, the feedback device **100** may apply a first voltage having a specific voltage value to the thermoelectric module **1000**. In the example of FIG. **60**, the first voltage may be a voltage used in outputting cold feedback.

In the graph of FIG. **60**, the x-axis indicates time, the y-axis indicates temperature, and a line **6020** indicates the temperature of the contact surface **1600**. In FIG. **60**, because the first voltage is applied to the thermoelectric module **1000**, after reaching a minimum temperature from an initial temperature, the temperature of the contact surface **1600** may be maintained within a predetermined temperature section. However, when the temperature of the contact surface **1600** is maintained within the specific temperature range for a long period, the extent to which the user perceives cold sensation may be lowered due to the above-described Weber's law. To prevent this, the feedback device **100** may perform a thermoelectric operation during the first period in Step **5810** and stop the thermoelectric operation during the second period in Step **5820**. Accordingly, after reaching the specific temperature section, the temperature of the contact surface **1600** may periodically rise and drop by a predetermined range or more. For example, after the temperature of the contact surface **1600** reaches the specific temperature range, the temperature of the contact surface **1600** may rise by a predetermined range during the second period and then drop by the predetermined range from the risen temperature during the first period. Here, the predetermined range may refer to a temperature range wider than the predetermined temperature section. Because of this, the user may receive cold heat in response to periodic temperature drop, and due to the cold heat, the user may perceive cold sensation better.

A line **6021** indicates a temperature change of the contact surface **1600** when Step **5810** and Step **5820** are repeatedly performed in the feedback device **100** while the temperature of the contact surface **1600** lasts within the specific temperature section. This will be described in detail with reference to FIGS. **61** and **62**.

FIG. **61** is a view for describing a temperature change of a contact surface due to controlling a thermoelectric operation according to an embodiment of the present disclosure.

Referring to FIG. **61**, the graph of FIG. **61** shows a temperature change of the contact surface **1600** when the feedback device **100** repeatedly performs Step **5810** and Step **5820**. As shown in the graph of FIG. **61**, the temperature of the contact surface **1600** may repeatedly rise and drop within a section between a first temperature tempo and a second temperature temp **2**. Due to such temperature rise and temperature drop, the user's cold sensation perception performance may be improved.

In an embodiment of the present disclosure, the user's cold sensation perception performance may be improved when a temperature difference between the first temperature temp **1** and the second temperature temp **2** is a threshold temperature difference or larger. This is because, when the temperature difference between the first temperature temp **1** and the second temperature temp **2** is lower than the threshold temperature difference, stimulation at a certain level or higher is not applied to the user, and according to the Weber's law, it is difficult for the user to perceive a change in cold heat.

In some embodiments of the present disclosure, the feedback device **100** may preset the threshold temperature difference. According to the Weber's law, the user may perceive a change in cold sensation only when a temperature of cold heat newly transferred to the user differs from a temperature of cold heat previously transferred to the user by a predetermined proportion or more. Accordingly, the threshold temperature difference may vary according to cold heat previously transferred to the user. Consequently, when the temperature of the contact surface **1600** is maintained within a specific range, the feedback device **100** may check temperatures within the specific range and use the temperatures within the specific range to set the threshold temperature difference.

In some embodiments of the present disclosure, the feedback device **100** may control the threshold temperature difference to occur at the contact surface **1600**. Specifically, the temperature variation of the contact surface **1600** in Step **5810** and Step **5820** may vary according to at least one of a level of voltage applied to the thermoelectric module **1000** in Step **5810** and Step **58020**, the first period in which a thermoelectric operation is performed, and a second period in which the thermoelectric operation is stopped. For example, when the second period is short, the amount of time in which the temperature of the contact surface **1600** rises is reduced, and accordingly, the temperature variation may be decreased. When the first period is short, the amount of time in which the temperature of the contact surface **1600** drops is reduced, and accordingly, the temperature variation may be decreased. In Step **5810** and **5820**, when a level of a voltage applied to the thermoelectric module **1000** is high, the temperature variation of the contact surface **1600** may be increased. The feedback device **100** may set the threshold temperature difference and adjust at least one of a level of the voltage applied to the thermoelectric module **1000** in Step **5810** and **5820**, the first period during which a thermoelectric operation is performed, and the second period during which the thermoelectric operation is stopped so that the temperature variation of the contact surface **1600** is the threshold temperature difference or higher.

FIG. **62** is a view for describing a temperature change of the contact surface due to controlling a thermoelectric operation according to another embodiment of the present disclosure.

Referring to FIG. **62**, a temperature change of the contact surface **1600** when the feedback device **100** repeatedly performs Step **5810** and Step **5820** is shown. As shown in the graph of FIG. **62**, the temperature of the contact surface **1600** may periodically repeat rising and dropping within the section between the first temperature temp **1** and the second temperature temp **2**. Here, within the section between the first temperature temp **1** and the second temperature temp **2**, a time proportion between a first time period t**1** that indicates a time at which the temperature of the contact surface **1600** rises and a second time period t**2** at which the temperature of the contact surface **1600** drops may vary. In the example of (a), the first time period t**1** and the second time period t**2** may be equal to each other. However, in the example of (b), the first time period t**1** may be shorter than the second time period t**2**, and in the example of (c), the first time period t**1** may be longer than the second time period t**2**.

In an embodiment of the present disclosure, the feedback device **100** may adjust the time proportion between the first time period t**1** and the second time period t**2**. Specifically, when the feedback device **100** outputs cold feedback, the first time period t**1** is a time during which a thermoelectric operation is stopped, and the second time is a time during which the thermoelectric operation is performed. When the feedback device **100** outputs hot feedback, the first time period t**1** is a time during which a thermoelectric operation is performed, and the second time period t**2** is a time during which the thermoelectric operation is stopped. The feedback device **100** may adjust the time during which a thermoelectric operation is performed and the time during which the thermoelectric operation is stopped and adjust the time proportion between the first time period t**1** and the second time period t**2** so that a user's degree of perception is improved.

For example, in some embodiments of the present disclosure, when the feedback device **100** outputs cold feedback, it may be beneficial for the user's cold sensation perception that a section in which the temperature of the contact surface **1600** drops is shorter than a section in which the temperature of the contact surface **1600** rises. In this case, as shown in (c), the feedback device **100** may control the thermoelectric module **1000** so that the second time period t**2** is shorter than the first time period t**1**.

When the feedback device **100** outputs hot feedback, it may be beneficial for the user's perception that a section in which the temperature of the contact surface **1600** rises is shorter than a section in which the temperature of the contact surface **1600** drops. In this case, as shown in (b), the feedback device **100** may control the thermoelectric module **1000** so that the first time period t**1** is shorter than the second time period t**2**.

FIGS. **63** to **65** are views for describing a temperature change of the contact surface due to controlling a thermoelectric operation according to still another embodiment of the present disclosure.

Referring to FIG. **63**, the graphs of FIGS. **63** to **65** show a temperature change of the contact surface **1600** when the feedback device **100** repeatedly performs Step **5810** and Step **5820**. However, in the graphs of FIGS. **63** to **65**, the first period during which a thermoelectric operation is performed and the second period in which the thermoelectric operation is stopped may be different. Specifically, in the graph of FIG. **63**, the first period, the second period, and the overall period may be set as 59.5 seconds, 0.5 seconds, and 60 seconds, respectively; in the graph of FIG. **64**, the first period, the second period, and the overall period may be set as 58 seconds, 2 seconds, and 60 seconds, respectively; and in the graph of FIG. **65**, the first period, the second period, and the overall period may be set as 50 seconds, 10 seconds, and 60 seconds, respectively. The graphs of FIGS. **63** to **65** may show the temperature change of the contact surface **1600** when voltages at various levels are applied to the thermoelectric module **1000**. Specifically, in the graphs of FIGS. **63** to **65**, the x-axis indicates time, the y-axis indicates temperature, lines **6001**, **6101**, and **6201** indicate surrounding temperature, lines **6010**, **6110**, and **6210** indicate temperature of the contact surface **1600** when a first voltage is applied, lines **6020**, **6120**, and **6220** indicate temperature of the contact surface **1600** when a second voltage is applied, lines **6030**, **6130**, and **6230** indicate temperature of the contact surface **1600** when a third voltage is applied, and lines **6040**, **6140**, and **6240** indicate temperature of the contact surface **1600** when a fourth voltage is applied. Here, the level of the voltage may be higher in the order of the first voltage, the second voltage, the third voltage, and the fourth voltage.

In an embodiment of the present disclosure, as shown in the graphs of FIGS. **63** to **65**, because the feedback device **100** repeatedly performs Step **5810** and Step **5820**, even in a section in which the temperature of the contact surface **1600** is maintained to be a specific temperature, a temperature rise and a temperature drop may be repeated within a predetermined temperature range. Due to the repeated temperature rise and temperature drop, the user's cold sensation perception performance may be improved.

In another embodiment of the present disclosure, as shown in the graphs of FIGS. **63** to **65**, as the proportion of the second period is higher in the overall period, a difference between the temperature of the contact surface **1600** in the first period and the temperature of the contact surface **1600** in the second period may be increased. For example, when the lines **6020**, **6120**, and **6220**, which indicate the temperature of the contact surface **1600** when the second voltage is applied, are compared, even when the voltage at the same level is applied, the difference between the temperature of the contact surface **1600** in the first period and the temperature of the contact surface **1600** in the second period may be increased as the second period in which the thermoelectric operation is not performed is longer.

In an embodiment of the present disclosure, the feedback device **100** may properly adjust the first period and the second period to improve the user's degree of perception. For example, in a case in which the threshold temperature difference indicating a temperature difference through which the user may perceive a change in cold sensation described above with reference to FIG. **61** is lower than a first threshold value, and a difference between the temperature of the contact surface **1600** in the first period and the temperature of the contact surface **1600** in the second period in FIG. **63** is higher than the first threshold value, when the feedback device **100** performs Step **5810** and Step **5820** according to the first period and the second period in FIG. **63**, the user may perceive a change in cold sensation.

In another example, in a case in which the threshold temperature difference is higher than the first threshold value but lower than a second threshold value, which is higher than the first threshold value, and a difference between the temperature of the contact surface **1600** in the first period and the temperature of the contact surface **1600** in the second period is higher than the second threshold value in FIG. **64**, the feedback device **100** may perform Step **5810** and Step **5820** according to the first period and the second period in FIG. **64** and improve the user's perception performance. However, in this case, because the difference between the temperature of the contact surface **1600** in the first period and the temperature of the contact surface **1600** in the second period in FIG. **65** may also be higher than the second threshold value, the user's perception performance may be improved even when the feedback device **100** performs Step **5810** and Step **5820** according to the first period and the second period in FIG. **65**. However, the second period in FIG. **65** may be longer than the second period in FIG. **64**, and because of this, the amount of temperature rise in FIG. **65** may be higher than the amount of temperature rise in FIG. **64**. However, according to circumstances, hot sensation may be provided to the user when the amount of temperature rise is high. Consequently, to improve the extent to which the user perceives cold sensation while not providing hot sensation to the user, when the threshold temperature difference is lower than the second threshold value, the feedback device **100** may perform Step **5810** and Step **5820** according to the first period and the second period in FIG. **64**.

The method according to an embodiment may be implemented in the form of a program command that is executable by various computer means and be recorded in a computer readable recording medium. The computer readable recording medium may include a program command, a data file, a data structure, and the like solely or in combination. The program command recorded in the medium may be particularly designed for the embodiment or may be known by one of ordinary skill in the computer software art and usable. Examples of the computer readable recording medium include hardware devices particularly configured to store and execute program commands such as magnetic media such as a hard disk, a floppy disk, and a magnetic tape, optical media such as a compact disk read-only memory (CD-ROM) and a digital versatile disk (DVD), magneto-optical media such as a FL optical disk, and semiconductor storage devices such as a ROM, a random access memory (RAM), and a flash memory. Examples of the program command include high-level language codes that are computer-executable by using an interpreter and the like as well as machine language codes such as those formed by a compiler. The above-mentioned hardware device may be configured to serve as one or more software modules to execute operations of the embodiment, and vice versa.

According to the present disclosure, thermal feedback can be provided to a user.

Further, according to the present disclosure, waste heat generated in a feedback device can be effectively dissipated.

Further, according to the present disclosure, cold sensation can be more effectively provided to a user.

Further, according to the present disclosure, a user's degree of thermal feedback perception can be improved.

Advantageous effects of the present disclosure are not limited to the above-mentioned effects, and other unmentioned effects should be clearly understood by one of ordinary skill in the art to which the present disclosure pertains from the present specification and the accompanying drawings.

Although embodiments of the present disclosure have been described above using limited embodiments and drawings, one of ordinary skill in the art should be capable of modifying and changing the above-described embodiments in various ways. For example, the above-described techniques may be performed in a different order from the above-described method, and/or the above-described elements such as a system, a structure, a device, and a circuit may be coupled or combined in a different form from the above-described method, or suitable results may be achieved even when the elements are replaced or substituted with other elements or their equivalents.

Therefore, other implementations, embodiments, and equivalents of the appended claims also belong to the scope of the claims below.

What is claimed is:

1. A feedback device comprising:

a thermoelectric module including a flexible substrate, a thermoelement disposed on the substrate configured to perform a thermoelectric operation for thermal feedback, and a contact surface disposed on the substrate configured to transfer heat generated by the thermoelectric operation to a user, wherein the heat is transferred through the substrate and the contact surface to an output for the thermal feedback; and

a feedback controller configured to control the thermoelectric module,

wherein:

the thermoelectric operation includes an exothermic operation and an endothermic operation,

the feedback controller controls the thermoelectric module so a temperature of the contact surface is maintained within a predetermined temperature range during a thermoelectric operation time interval after the temperature of the contact surface reaches a target temperature; and

the feedback controller controls the thermoelectric module so a temperature rise or a temperature drop that exceeds a predetermined threshold value, periodically occurs in the contact surface after the temperature of the contact surface reaches the predetermined temperature range.

2. A feedback device for providing a thermal feedback including at least one of a hot feedback and a cold feedback, the feedback device comprising:

a thermoelectric module comprising a flexible substrate, a thermoelement disposed on the substrate configured to perform a thermoelectric operation for the thermal feedback, and a contact surface disposed on the substrate configured to transfer heat generated by the thermoelectric operation to a user; and

a feedback controller configured to control the thermoelectric module,

wherein the thermoelectric operation including at least one of an exothermic operation and an endothermic operation,

wherein the heat being transferred through the substrate and the contact surface to an output for the thermal feedback,

wherein the feedback controller controls the thermoelectric module so a temperature rise and a temperature drop occur in the contact surface periodically after a temperature of the contact surface reaches a target temperature related to the thermal feedback, and

wherein the temperature of the contact surface is maintained within a predetermined temperature range while the temperature rise and the temperature drop occur.

3. The feedback device of claim **2**, wherein:

the feedback controller applies a first electric signal having a constant voltage or a constant current to the thermoelectric module to cause that the temperature of the contact surface reaches the target temperature related to the thermal feedback for providing a cold sensation to the user, and

the feedback controller applies a second electric signal having a duty cycle to the thermoelectric module to cause that the temperature of the contact surface repeats the temperature rise and the temperature drop for enhancing the cold sensation of the user.

4. The feedback device of claim **3**, wherein the first electric signal and the second electric signal cause the thermoelectric module to perform the endothermic operation.

5. The feedback device of claim **4**, wherein:

waste heat is accumulated inside the feedback device while the thermoelectric module performs the endothermic operation by an on-period of the duty cycle; and

the temperature of the contact surface rises due to the waste heat in an off-period of the duty cycle.

6. The feedback device of claim **5**, wherein:

the feedback device further comprises a heat radiator configured to dissipate at least a portion of the waste heat to the outside of the feedback device; and

while the portion of the waste heat is dissipated to the outside of the feedback device by the heat radiator, the temperature of the contact surface is maintained within the predetermined temperature range.

7. The feedback device of claim **5**, wherein:

the feedback controller controls the thermoelectric module so a temperature variation of the contact surface between the on-period of the duty cycle and the off-period of the duty cycle is larger than or equal to a threshold temperature difference, and

the threshold temperature difference indicating a temperature difference that allows the user to perceive a temperature change.

8. The feedback device of claim **7**, wherein the temperature variation of the contact surface is adjusted according to a proportion between the on-period of the duty cycle and the off-period of the duty cycle.

9. The feedback device of claim **7**, wherein a proportion of the off-period .of the duty cycle to the on-period of the duty cycle is higher than or equal to 0.9.

10. The feedback device of claim **2**, wherein the target temperature is lower than an initial temperature.

11. The feedback device of claim **10**, wherein the predetermined temperature range is higher than the target temperature and lower than the initial temperature.

12. The feedback device of claim **2**, wherein the feedback controller applies a third electric signal having a constant voltage, a constant current or a duty cycle to the thermoelectric module to cause that the temperature of the contact surface reaches the target temperature related to the thermal feedback for providing a cold sensation to the user and repeats the temperature rise and the temperature drop for enhancing the cold sensation of the user.

13. The feedback device of claim **2**, wherein:

the feedback controller applies a fourth electric signal having a constant voltage or a constant current to the thermoelectric module to cause that the temperature of the contact surface reaches the target temperature related to the thermal feedback for providing a hot sensation to the user, and

the feedback controller applies a fifth electric signal having a duty cycle to the thermoelectric module to cause that the temperature of the contact surface repeats the temperature rise and the temperature drop for enhancing the hot sensation of the user.

14. The feedback device of claim **13**, wherein the fourth electric signal and the fifth electric signal cause the thermoelectric module to perform the exothermic operation.

15. The feedback device of claim **13**, wherein the target temperature is higher than an initial temperature.

16. The feedback device of claim **15**, wherein the predetermined temperature range is lower than the target temperature and higher than the initial temperature.

17. The feedback device of claim **2**, wherein the feedback controller applies a sixth electric signal having a constant voltage, a constant current or a duty cycle to the thermoelectric module to cause that the temperature of the contact surface reaches the target temperature related to the thermal feedback for providing a hot sensation to the user and repeats the temperature rise and the temperature drop for enhancing the hot sensation of the user.

18. A method for providing a thermal feedback including at least one of a hot feedback and a cold feedback, the feedback device comprising:

a thermoelectric module comprising a flexible substrate, a thermoelement disposed on the substrate configured to perform a thermoelectric operation for the thermal feedback, and a contact surface disposed on the substrate configured to transfer heat generated by the thermoelectric operation to a user; and

a feedback controller configured to control the thermoelectric module,

wherein:

the thermoelectric operation includes at least one of an exothermic operation and an endothermic operation, and

the heat is transferred through the substrate and the contact surface to an output for the thermal feedback, the method comprising:

controlling the thermoelectric module such that a temperature of the contact surface reaches a target temperature related to the thermal feedback, and

controlling the thermoelectric module so a temperature rise and a temperature drop occur in the contact surface periodically after the temperature of the contact surface reaches the target temperature related to the thermal feedback,

wherein the temperature of the contact surface is maintained within a predetermined temperature range while the temperature rise and the temperature drop occur.

19. A non-transitory computer readable medium storing a program to execute the method of claim **18**.

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